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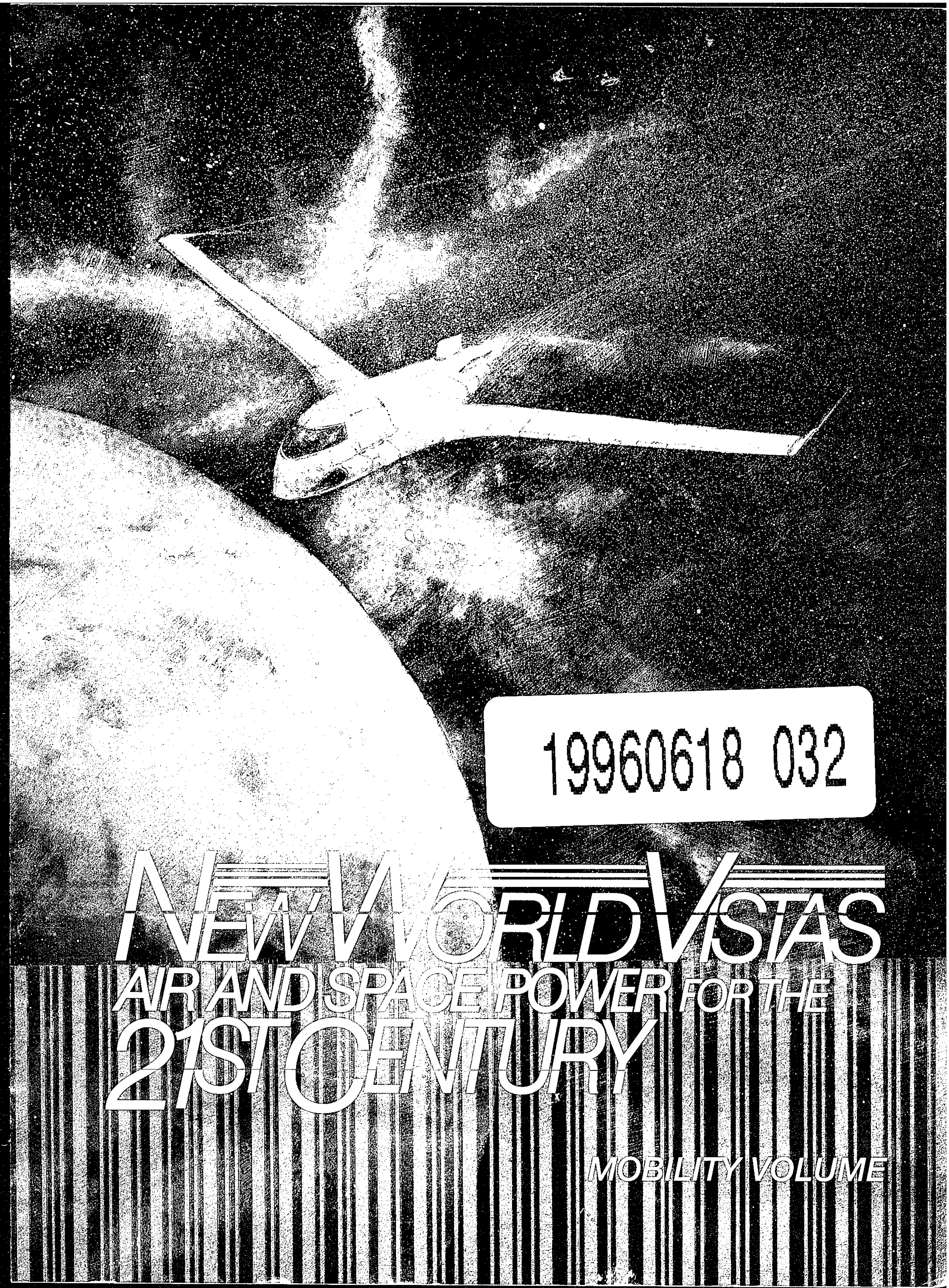

NEW WORLD VISTAS

AIR AND SPACE POWER FOR THE 21ST CENTURY

MOBILITY VOLUME

NEW WORLD VISTAS
AIR AND SPACE POWER FOR THE 21ST CENTURY

MOBILITY VOLUME

This report is a forecast of a potential future for the Air Force. This forecast does not necessarily imply future officially sanctioned programs, planning or policy.

Executive Summary

The political changes around the world continue to reduce available overseas base support. As a result, US military forces are primarily based in the continental US, while global presence is still required. The potential conflict areas are not well defined, and may be anywhere in the world. Thus, while reduction in tensions with communist countries have brought about reductions in military forces, the demands on the mobility assets are as great or greater than ever. The Air Mobility Command (AMC) must be prepared to conduct global air mobility missions. AMC must also support peacekeeping and humanitarian missions where a hostile environment is possible. Further, the proliferation of cheap, heat-seeking missiles increases aircraft risk even in remote, poorly developed countries.

After examining the mobility missions and identifying their shortcomings, advanced technologies were reviewed to determine how they could solve these problems. A number of advanced systems were postulated to meet the mobility needs. These were then evaluated against criteria which included:

- Contribution to mobility mission effectiveness
- Affordability
- Supportability, including training
- Technology maturity
- Applicability of commercial development and/or dual use

The systems embodying the most revolutionary technologies for potential mobility improvements were then identified as follows:

- Information Dominance System
- Global Range Transport
- Precision/Large Scale Airdrop
- Directed Energy Self-Defense System
- Virtual Reality Applications

The key technologies recognized as needed were:

- Wideband, secure, world-wide information networks
- Multi-level data fusion and information distribution
- High temperature materials for advanced turbo fan engines
- Low cost composites for airframes
- Airborne lasers for self defense
- Synthetic sensory environment for virtual reality applications
- Airborne wind-measurement sensors

Information Dominance System

The US Air Force must erect a system to provide information dominance in the 21st century. The air mobility part of this system should consist of worldwide communication networks that are timely, accurate, and dependable. It should be a globally netted system with protected circuits and computers, which process fully automated fused intelligence and other on demand information. This capability can be provided by interconnected satellites in various orbits as

well as fiber optic ground nets. User friendly information will flow from surveillance/reconnaissance, weather, navigation and other information gathering assets. Then, it can be merged in fusion computers and provided to AMC's airborne and ground personnel. Near perfect real-time situational awareness will be integrated in the command, control, communication, computers and intelligence (C^4I) network. It will include threat updates, airfield information, refueling rendezvous and other mission-relevant data as well as intransit visibility as to cargo and passengers.

Global Range Transport

Improvements in engine materials will continue to permit higher cycle temperatures and better efficiencies. Present trends towards low-cost composite structures will also continue. Such technological advancements could lead to an unrefueled global transport. This aircraft could be equally attractive to the commercial market and thus doubly affordable (first as a commercial derivative, second by reducing the need for tankers). Alternatively, modular design and flexible manufacturing technology may achieve affordability breakthroughs without relying on the use of configurations driven by commercial requirements. This aircraft will be applicable to cargo, passenger, aeromedical evacuation, and combat aircraft refueling support.

This new transport is estimated to have a gross weight of approximately 900,000 pounds or less, and carry a 150,000 pound payload for 12,000 nautical miles. Ideally, the payload should be compatible with standardized containers to permit intermodal operation.

The technologies needed to get this capability are extensions of existing programs. The Integrated High Performance Turbine Engine Technology (IHPTET) program is directed towards 20-25% improvement in performance through higher cycle temperatures and better efficiencies. The developments with injection molded composite ribs for the F-22 gives promise of greatly reduced part count and simplified composite parts. These should lead to more affordable composites which in turn would permit higher aspect ratio designs. The field of Engineered Materials covers both of these key technology areas: 1) high temperature turbine materials for jet engines, and 2) the development of advanced composites. Other innovative concepts, such as dual fuselages, offer the promise of higher aerodynamic efficiency as well as improved structural efficiency. Improvements in all these technologies will result in the projected performance.

Precision Airdrop

Current delivery airdrop suffers from large delivery inaccuracies. Precision airdrop (within 100 feet of target) facilitates delivery of cargo to forward areas. It would also be more compatible with flexible, precision strike systems. By reducing overseas and forward bases, ground handling equipment, ground vehicles, and associated personnel, the operation could reduce delivery cost and improve timeliness.

A family of delivery solutions, all integrated with a core support system on board the aircraft, will provide the most effective precision airdrop system. The precision airdrop system comprises the aerial delivery system in combination with the carrier aircraft, and includes the modifications, equipment, or techniques required to enable the aircraft to complete the specific airdrop mission. These components will include accurate aircraft and target location

(precision GPS), knowledge of wind profile, and knowledge of aerial delivery system flight characteristics. Both parachute and standoff delivery systems will be supported. The important task for technology is the integration of wind measurement (LIght Detection And Ranging), Global Positioning System (GPS) based navigation and targeting, improved aerial delivery systems, and many subsystem improvements. LIDAR also has significant potential for commercial in-flight air turbulence detection.

Directed Energy Self-Defense System

Surface-to-air, or air-to-air missiles, are a major threat to mobility aircraft performing cargo airlift, passenger airlift, airdrop operations, medical evacuation, special operations and refueling missions. A system needs to be developed to counter this threat. The key component of this system will be a laser (or high power microwave) system that can be fired to defend the air mobility vehicle. This will provide the aircraft with an ability to defeat advanced surface-to-air, or air-launched missiles. There must also be included in the system a means to provide missile warning, a dedicated high-performance computer to predict the in-coming missile's trajectory, and to establish fire control data for the directed energy device.

This application of a rapidly developing technology is most appropriate. Whereas tactical aircraft often have the maneuverability to evade ground-launched missiles, air mobility vehicles do not. In addition, tactical aircraft have space and power restrictions while mobility vehicles have the space and can provide the necessary power. Hence, they are a prime platform for a first application of this new technology.

Such a small, energy frugal system is estimated to weigh less than 500 pounds, be packaged in a 3' X 2' X 2' space, and be deployable internally or in a pod. Prime power requirements for the very short-duration of laser firing should be less than 150 kilowatts.

Virtual Reality Applications

Advanced Virtual Reality (VR) systems will complement traditional training simulators and enhance mission effectiveness. VR will be applicable to all types of training (flight, maintenance, loading, etc.), and will be extended to rehearsal training for important operational missions into remote areas. Since these missions will require worldwide data links, AMC must ensure their mobility needs are included in the communication nets.

As current VR systems are improved and computer capabilities expand, the systems will be of more and more benefit to AMC. This will be particularly true as wide band data links are developed which can tie worldwide locations together. Commercial and military data links will be used. Synthetic sensory environments (e.g. three-dimensional holographic displays), computational power, and computer generated images will be key technologies.

Summary

The mobility panel final summary was developed by assessing the selected systems against the panel charter (Appendix A). The charter complied with major elements of the charge to the SAB by the Secretary of the Air Force and the Air Force Chief of Staff. This summary is shown in Table ES-1.

Table ES -1: Mobility Recommended Systems vs Panel Charter

	Information Dominance	Global Range Transport	Precision/ Large Scale Airdrop	Directed Energy Self-Defense	Virtual Reality Applications
Importance to Air Force	Vital for C^4I, supports RTIC	Supports all global reach missions	Improves flexibility and survivability	Improves survivability	Joint exercises and training
Effectiveness benefit	Improves C^2 and survivability	Improves reaction time and reliability	Reduces forward infrastructure	Increases probability of mission success	Improves mission effectiveness
Affordability	Moderate	Good	Moderate	Moderate	No impact
Key Technical Issues	Wide-band global C^4 and Nav nets	Low-cost composites, very high performance engines	Wind Measurement	Low power laser and system integration	Synthetic environment generation, physical sensory systems
Commercial Development	Yes, but needs tailoring	Probably	Limited	No	Yes, but needs tailoring

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1.0 Introduction

In the spirit of the *New World Vista* study, the *Mobility Panel* set out to select areas of rapidly changing technology which could have an impact on improving the mission capability of Air Mobility Command (AMC). Before discussing the nature of this selection process it should be recognized that air mobility embodies a very broad spectrum of activity. The nature of this responsibility is covered in Section 2 of this report. The role of AMC in *National Military Security* is brought out, the *Operational Objectives* are discussed, and the specific key *Operational Tasks* are delineated. Also provided are a large number of the deficiencies AMC has already identified.

A point to be made about the tasks and deficiencies identified in Section 2 is that not all the desired improvements need to rely on advanced technology. Many can be done right now, but need support and funding. A good example is that of the global positioning system (GPS). The value of GPS has been increasingly recognized over a number of applications. As a particular example, its use as a powerful way to obtain precision air drop capability has been brought out. This has been recognized, good work is underway, and the feeling is that this work will continue. Thus, while the Mobility Panel considers this application as high priority, it has not been specifically included in their high priority listing because of the efforts already underway.

Charter or Guidelines

In the process of selecting areas of rapidly changing technologies applicable to the *Mobility Mission* the Mobility Panel used a charter based on the following guidelines:

a. Identify most revolutionary technologies

b. Evaluate impact on future systems

c. Consider impact on affordability of mobility mission, and

d. Identify which technologies can be obtained by capitalizing on commercial development or have dual use

Following the guidelines, the panel selection process went essentially as follows:

1. Identify missions, requirements and needs
2. Identify needs which technology could help solve
3. Relate needs to advanced technologies
4. Postulate future systems affecting improvements in mobility operations, utilizing advanced technologies
5. Establish evaluation and selection criteria
6. Evaluate proposed systems and select most promising
7. Coordinate with technology panels (cross talk with the Information, Directed Energy, Aircraft and Propulsion, and Materials panels)
8. Prepare detailed description and assessment for selected systems and

9. Emphasize technology advances required

The possible future systems that were identified are indicated in Section 4 of this report. The prioritized top five future systems selected are presented and discussed in detail in Section 6. The final conclusions and recommendations reached are provided in Section 7.

The Approach and Problem Selection

An indication of the nature of the problem areas that were considered is given by the following listing:

More range
Faster response times
Better communication
Improved all-weather operation
Real-time in cockpit (situational awareness)
Cheap, precision airdrop
Better material handling
Better training
Improved refueling capability
Improved reliability and inflight trouble shooting and
Improved defensive systems

2.0 Air Mobility Operational Requirements

Air mobility supports America and National Military Strategy across the spectrum of conflict; from peacetime operations for American global interests, to major regional contingencies and nuclear deterrence. This mission is accomplished through airlift of cargo and passengers and air refueling of fighter, bomber, tanker, airlift, and special operations aircraft.

Mobility Operational Objectives

Mobility's operational objectives are power projection, force sustainment, and humanitarian or peacekeeping support. Figure 2.0-1 below illustrates the relationship of the air mobility mission areas to operational objectives and then to the specific operational tasks. Operational tasks are those capabilities that must be available in order to achieve one or more operational objectives.

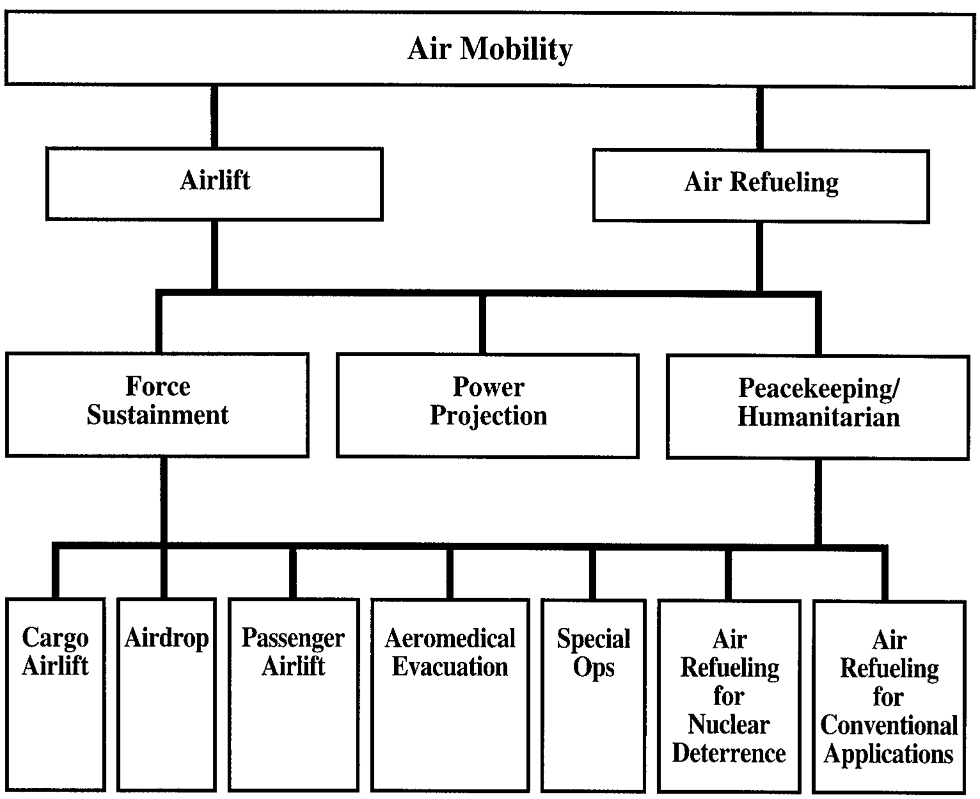

Figure 2.0-1 Air Mobility Mission

Operational Tasks

The air mobility operational tasks form the cornerstone of national security strategy and are expected to remain essential for the foreseeable future. The operational tasks are described in the following pages.

Airlift of supplies and equipment requiring processing, loading, and subsequent air-land movement of the following categories of cargo:

Bulk: General cargo, typically preloaded on pallets and transportable by common cargo aircraft.

Oversize: Cargo requiring a C-130 or larger. Typically larger than one 463L pallet.

Outsize: Cargo transportable normally only by C-5 or C-17.

Rolling Stock: Equipment that can be driven or rolled directly into the cargo compartment.

Special: Items requiring specialized preparation and handling procedures, such as space satellites.

Airlift provides speed and flexibility in deploying, employing, and sustaining combat forces. This task directly supports the war fighting commander with time-critical cargo and has a significant impact on the outcome of any contingency. Airlift is the most responsive and flexible of the strategic mobility options: surface, afloat prepositioning, sealift, or airlift. With a post-Cold War force that is primarily CONUS-based, rapid power projection is essential for establishing and reinforcing a US or multi-national presence. Airlift will deliver the bulk of the initial firepower in future conflicts. This task typically requires, at the receiving site, materials handling equipment (MHE), on- and offload support personnel, and facilities. Movement of nuclear weapons require special security, routing, and overflight clearances.

The Mobility Requirements Study Bottom-Up Review Update (MRS BURU), established the existing airlift requirement at 49 to 52 million ton-miles per day (MTM/D). The process of establishing the airlift requirement employed sophisticated airlift system and wargaming simulation models. The analysis modeled aircraft loading, movements and cargo delivery on a Time-Phased Force Deployment Data (TPFDD) timeline established by the Joint Chiefs of Staff (JCS) to meet the needs of supported theater Commanders in Chief (CINCs). The models computed timelines for delivery and wargames then assessed the resultant impact to combat effectiveness. This assessment of delivered forces' ability to achieve their objectives at an acceptable level of risk and confidence was an iterative process and established the airlift requirement for the foreseeable future. Figure 2.0-2 depicts projected strategic airlift fleet capability in relation to the MRS BURU requirement.

The strategic airlift capability does not meet the defense planning guidelines (DPG) two major regional contingencies (MRC) requirement per MRS BURU analysis until FY05. Limited capability exists to deliver outsize and oversize cargo to austere fields. The low reliability of aging aircraft such as the C-5, further inhibit AMC's ability to deliver cargo. The C-5 is the only aircraft fully fielded and capable of delivering outsize cargo and it does not routinely operate into short, poorly equipped airfields. The C-141 is scheduled to retire by FY06 while C-17 and NonDevelopmental Airlift Aircraft (NDAA) acquisition profiles are delayed. MHE is in short supply and poor condition. AMC has only 78% of the 40K loaders required. The inventory of commercial wide body capable loaders is only 49% of the established requirement. AMC plans to accelerate the 60K loader and begin procurement of a new small loader; both will be able to support both military aircraft as well as commercial wide body aircraft.

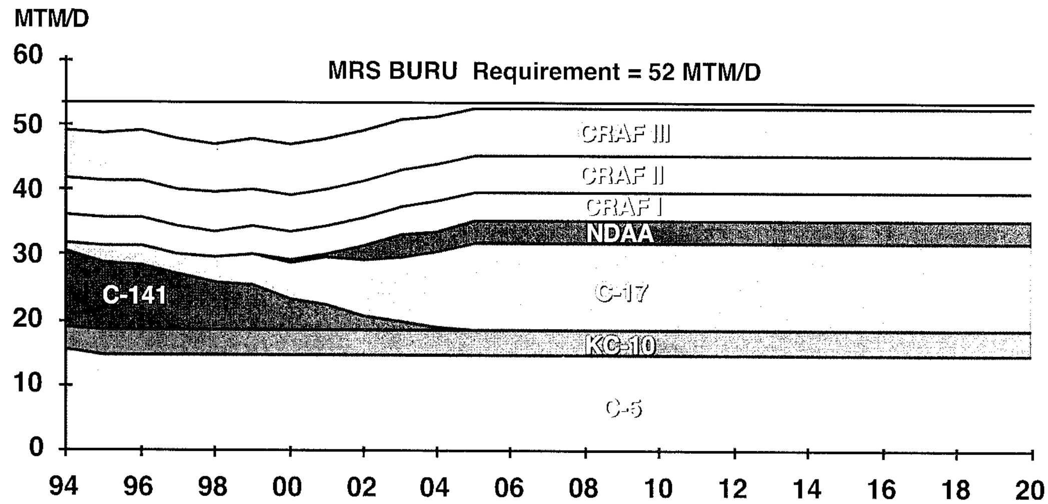

Figure 2.0-2: Strategic Airlift Capability

Airlift of Personnel

While all AMC organic aircraft can carry some passengers, planning factors assume 90% of all passengers during a large scale contingency will travel by contract commercial carriers in the Civil Reserve Air Fleet (CRAF). Troop movements must be carefully planned to arrive in theater with their equipment. MRS BURU set the passenger requirement at 136 wide-body equivalents (WBEs).

Special Air Missions (SAMs) use specially configured aircraft with extensive air-to-ground communications to support the President and Vice President of the United States, cabinet and congressional delegations, and other senior statesmen. These missions are time critical, often classified, and frequently require operations at civilian airports. In addition to SAMs, Operational Support Airlift (OSA) provides routine airlift of passengers throughout the DoD system as well as wartime movement of priority cargo and passengers in support of operational requirements.

Airdrop of Troops, Supplies, and Equipment

Airdrop is the employment and resupply of forces through the aerial delivery of troops and equipment without landing the aircraft. Formation operations are essential for adhering to the principles of mass and security. The airdrop capability directly supports the JCS requirement for an immediate response capability to deploy airborne forces throughout the world. This is the basis for maintaining strategic airdrop capabilities. While airland is the preferred method of deploying forces, the capability to airdrop troops and equipment is a crucial capability that remains an integral part of Army doctrine. Currently, the C-141 is the aircraft relied on for performing the strategic brigade airdrop mission. The C-17 just completed airdrop validation and will begin integration into the airdrop mission.

This operational task requires additional airborne communications and generally launches on short notice, requiring rapid and close mission planning and coordination with the user. The

strategic brigade airdrop also produces an intense MHE requirement to support the rapid rigging and onload of airdrop platforms at the staging site. Such intense activities create a significant operations security (OPSEC) challenge. These airdrop aircraft must be able to fly in a non-navaid environment, conduct formation air refuelings, and participate in formations of up to 100 aircraft. Finally, crews and troop commanders need near real-time situational awareness of the battlefield and communications with ground forces in order to react appropriately to the dynamic character of combat operations.

Aeromedical Evacuation (AE)

AE is the air movement of patients to appropriate medical care facilities. Movement of patients normally requires qualified aeromedical crewmembers. All air mobility aircraft maintain some capability to support AE giving some capability to respond to short notice taskings. Theater assets are the primary aircraft to move patients from forward operating locations to a centralized staging area. Civil carriers, augmented by organic aircraft, perform the intertheather missions from these staging areas to CONUS care facilities. These missions frequently require special air traffic control considerations to comply with patient driven altitude/pressurization restrictions as well as special aircraft systems for medical equipment. In addition to the C-9 and other aircraft, we count heavily on the C-17 and CRAF to fill the aeromedical evacuation role. A shortfall in meeting the wartime CRAF requirement exists.

Current CRAF AE Boeing 767 commitments meets less than half the requirement. In addition, only 33 of their 44 required AE shipsets are serviceable. The current Boeing 767 patient on/offloading is slow and impacts patient care and aircraft throughput. Current AE support equipment, such as the spinal cord immobilization system, is non-supportable. Most deployable medical systems are not AE certified and a portable gaseous oxygen system is required. Joint service coordination is needed to procure and certify new AE equipment. Feasibility of equipping other aircraft to fill the AE role, modifying shipsets, as well as improving incentives to increase CRAF participation are being explored.

Airlift Support for Special Operations

Specialized airland/airdrop support for special operations is needed for joint or combined contingencies, low intensity conflict, and other missions as directed by the National Command Authorities (NCA). This includes augmenting special operations missions through the insertion, resupply, or extraction of special operations forces. Special operations missions may be covert, clandestine, or overt. Aircrews must be capable of night vision goggle (NVG) operations and unique procedures that enhance their ability to conduct special operations (landings, tactical onloads and offloads, forward air refueling, and airdrop) at night.

Air Refueling for the Single Integrated Operational Plan (SIOP)

SIOP air refueling operations are conducted in four phases: force generation; execution; employment; and survival, recovery, and reconstitution. During increased readiness conditions, SIOP-assigned units generate aircraft and assume alert to support pre-, trans-, and post-strike bombers. SIOP-committed tankers refuel USSTRATCOM Command and Control aircraft and reconnaissance support sorties. These forces support USSTRATCOM and interface with its command and control (C2) systems. Aircraft on alert are kept ready for immediate launch.

These missions may be conducted in a nuclear detonation environment, leading to electromagnetic pulse, flash blindness and routing problems.

Air Refueling during contingency operations

Air Refueling enables rapid force projection and sustainment of conventional role bombers, fighters, tankers, airlift, and special operations aircraft by minimizing payload/fuel/range trade-offs. This decreases reliance on en route staging bases and host nation support while speeding combat forces to the theater of operations. As demonstrated in DESERT SHIELD/ STORM, the ability to air refuel served as a force multiplier, expanding both reach and combat capability of US and coalition forces in theater. USAF air refueling also routinely supports Navy, Marine, and allied aircraft which unique system and procedural requirements. Long-range air refueling also supports strike forces launching from CONUS bases.

Air Refueling Capability and Requirements

The air refueling fully mobilized wartime capability is shown below. The capability and requirement for air refueling is measured in million pounds of fuel per day (MPF/D). It is based on FY96-01 DPG scenarios and War Mobilization Plan commitments. This capability is based on projected mission capable rates and assumes the KC-135's primary role is air refueling. There are 26 KC-135s withheld for airlift missions. The dual role KC-10s can swing between air refueling and airlift as the warfighting commander's requirements vary. Fifteen KC-10s are dedicated for air refueling, 37 allocated to airlift tasks, and 2 for schoolhouse training. The shortfall is 9 MPF/D or 14% of the total air refueling requirement.

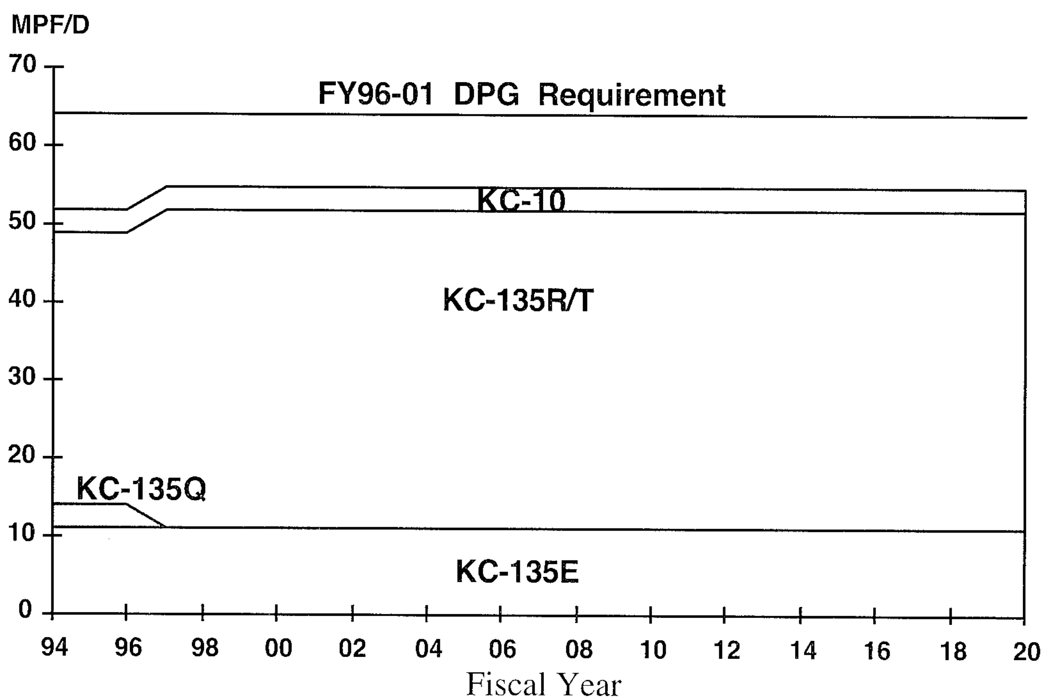

Figure 2.0-3: Air Refueling Capability

Infrastructure/Equipment Deficiencies with Likely Technological Solutions

Airlift and air refueling operations around the globe are dependent on a highly developed aircraft support and information infrastructure. Home bases must be able to generate, recover, and reconstitute mobility resources in rapid succession. The en route support system must service large numbers of transient airlift aircraft and their passengers and cargo. The information infrastructure must also provide the capability to command and control airlift and air refueling resources to provide commanders with required data concerning aircraft and mission requirements. The Mobility Requirements Study (MRS) documents the impact of an absence of en route locations in the European theater (Major Regional Contingency - East) and shows how the loss of key locations will significantly delay closure time. In addition, analysis using the Major Regional Contingency - West (Pacific Theater) determined that denied access to specific off-load and recovery bases present dramatic impacts that increase closure time and risk substantially.

While many of these problems could be solved with increased quantities of present equipment; better, more affordable solutions may be available using advanced technology. The needs in this regard are:

- Global command and control
- Very accurate worldwide navigation
- Realtime situational awareness
- Improved aircraft survivability
- Better material handling equipment
- Improved reliability and maintainability
- Total asset visibility/In-transit visibility
- Improved delivery systems
- Better training systems
- Global range
- Higher speed

3.0 Mobility Needs Summary

Technology can help provide solutions to many of the mobility problems, whether in the airlift or refueling mission areas. For example, the development of long-range capability could eliminate the refueling problem of transport operations.

The various problems and associate needs have been identified in Section 2.0. These needs, with additional explanatory comments, are summarized in the following:

- Global command, control, communications, computers and intelligence (C^4I) - use of worldwide C^4I nets to integrate with the AMC aircraft and command centers to provide secure, reliable, instantaneous command and control.
- Very accurate worldwide navigation - accuracy of one meter or better when needed for all mobility aircraft. Particularly applicable to air drop, special operations and tankers.
- Realtime situational awareness - Air mobility crews need to have current threat information and other intelligence data available in the cockpit to ensure highest probability of mission success.
- Improved aircraft survivability - availability of missiles in third world countries is prevalent today. Air mobility aircraft need protection from these and other threats in order to do their job.
- Better material handling equipment - the use of commercial transportation is limited by the ability to load and unload them at austere bases. Present equipment does a good job, but it must be flown in first in order to be available.
- Improved reliability and maintainability - Better reliability can improve mission completion capability. Improved maintainability would mean fewer maintenance personnel, fewer spares, etc.
- Total asset visibility/In-transit visibility - need to know where each item being transported is at all times (similar to Federal Express).
- Improved delivery systems - low cost precision airdrop could eliminate much ground equipment. Drop weight needs to be increased, precision drop improved and cost reduced.
- Better training systems - virtual reality should permit better training in all areas (maintenance, loading, flying, etc) plus mission planning.
- Global range - better materials, aerodynamics and engines should permit long range operation without refueling.
- Higher speed - Future conflicts may require faster reaction times.

These needs are found to be spread throughout the various mobility missions as summarized in Table 3.0-1.

Table 3.0-1. Mobility Tasks and Needs

	Operational Tasks					
	Cargo Airlift	Passenger Airlift	Airdrop	Air Refueling	Med Evac	Special Ops
Global Comm	X	X	X	X	X	X
Global Nav Accuracy	X	X	X	X	X	X
Situation Awareness	X	X	X	X	X	X
Aircraft Survivability	X	X	X			X
Improved R&M	X	X		X		X
Better Material Handling Equipment	X		X		X	X
Total Asset Visibility	X	X	X		X	X
Improved Delivery Systems	X		X	X		X
Better Training System	X	X	X	X	X	X
Global Range	X	X			X	
Higher Speed	X	X		X	X	X

The needs identified draw on many different advanced technologies. These relationships are illustrated in Table 3.0-2.

Table 3.0-2. Mobility Needs and Technologies

	Technologies						
	Sensors	Info	Space	Aircraft/ Propulsion	Materials	Biotech	Directed Energy
Global Comm		X	X				
Global Nav Accuracy	X	X	X				
Situation Awareness	X	X	X				
Aircraft Survivability	X	X		X	X	X	X
Improved R&M	X	X		X	X	X	
Better Material Handling Equipment				X	X		
Total Asset Visibility	X	X			X	X	
Improved Delivery Systems				X	X	X	
Better Training System	X	X	X	X	X	X	
Global Range				X	X	X	
Higher Speed				X	X	X	

4.0 Possible Future Mobility Systems

The Mobility Panel complied a list of nineteen possible future systems which they felt could improve mobility operations utilizing advanced technologies. These systems were based on the New World Vista study guidelines as stated in Section 1, the mobility mission shortfalls as identified in Section 2, and the technology needs as summarized in Section 3. A listing of the systems selected is provided in Table 4.0-1.

Table 4.0-1: Possible Future System

1*	Global range transport
2	Supersonic military transport
3*	Information dominance system
4	Wing in ground effect transport
5	Global navigation system
6	Advanced material handling equipment
7*	Precision/large scale airdrop
8*	Virtual reality training
9*	Directed energy self-defense system
10	Unmanned transport
11	Containerized, intermodal system
12	Rocket transport
13	Air refueling transfer craft
14	Stealth transport
15	Twin fuselage transport
16	Modular transport aircraft
17	Improved refueling system
18	VTOL special operations
19	Sea-based transport

Sections 4.1 through 4.19 provide a description of each possible system, discuss their applicability to the mobility mission, list possible benefits, and state the technology status or challenges to fielding the new system. These systems are used as the basis for ranking in Section 5. Finally, those with highest (*) ranking are discussed in detail in Section 6.

4.1 Global Range Transport

This system takes advantage of major advances in propulsion and materials technology. The result is a transport airplane of less than a million pounds take-off gross weight, capable of carrying 150,000 pounds of payload 12,000 nautical miles. With this performance capability the transport will be able to have unrefueled global reach. This airplane would support cargo and passenger airlift, aeromedical evacuation, and could be the basis for use as a tanker. Thus it would have broad application to air mobility.

Benefits

The benefits to the Air Force associated with the Global Range Transport (GRT) are many. Its unrefueled global range provides great flexibility in mobility operations. All the enroute support associated with inflight refueling or ground base staging can be focused on other missions. Further, use of modern design and commercial type subsytems should result in major reliability improvements. These reliability improvements in turn result in greater availability and fewer airplanes required to support the mobility missions. Finally, the technologies envisioned will be extremely attractive to commercial cargo carriers. Thus commercial development of such a transport is a distinct possibility - in which case a military adaptation would be possible. Such an approach would result in an extremely affordable global range Air Force transport.

Technology Needs

A number of technology advances are needed to develop an unrefueled GRT. Such an airplane represents a major technology advance over any existing airplane. Four needed key technologies are:

- Improved propulsion efficiency (advanced engines based on improved materials, higher cycle temperatures and bypass ratios). The IHPTET initiative should be pursued to bring this capability to the design of the global range transport.
- Improved aerodynamic efficiency (advanced wing design and innovative configurations)
- Light weight and low cost advanced materials
- Innovative concepts for design and build of the airplane utilizing digital technology and teaming

4.2 Supersonic Military Transport

Continued advances in supersonic aerodynamics, high temperature turbojets and advanced materials will make it possible to have a military supersonic transport. This vehicle will cruise at Mach number 2.4 and carry 50,000 pounds (150 personnel) for 5,000 nautical miles. The vehicle take-off weight will be approximately 500,000 pounds.

Benefits

Future warfare will require much quicker reaction times and smaller payloads. A supersonic military transport would provide the capability to deliver military personnel, advanced precision weapons, and appropriate resupply within hours to almost anywhere in the world. This fast reaction capability could be critical to deterring or containing potential conflicts. These vehicles would also have great value for special air missions.

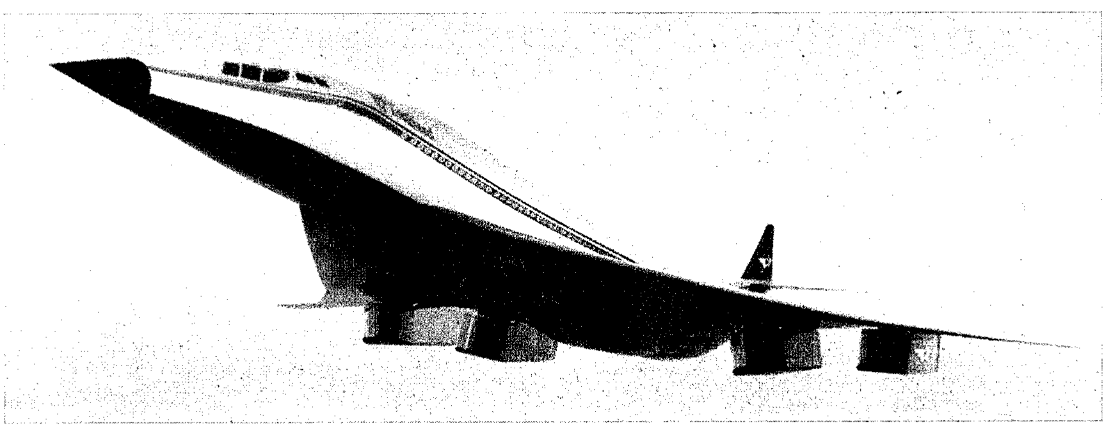

Figure 4.2-1 Supersonic Military Transport

Technology Needs

A key requirement is for an advanced turbojet engine with high turbine inlet temperatures (+300° from today).

Continued aerodynamic development of efficient supersonic cruise configuration is needed. Development of laminar flow control would enhance the capability. Sonic boom problems must also be minimized.

Development of low cost, high strength, light weight materials is a must. These will probably be advanced composites - but not necessarily boron/epoxy.

4.3 Information Dominance System

The revolution in information technology led by the United States provides the US Air Force an unequaled opportunity to exploit and seize the next vista in aerospace employment on the 21st century battlefield. The information spectrum is composed of numerous critical elements which in combination will strongly enhance Air Mobility Command effectiveness in future operations, from peacekeeping through warfighting. The information spectrum has direct applicability across all the AMC mission areas of cargo airlift, passenger airlift, air refueling, medical evacuation, special operations and airdrop and will increase efficiency in all these areas.

The proposed system should consist of worldwide communication networks that are timely, accurate, and dependable. Their purpose should be to provide autonomous broadcast, or mission-coordinated information, in this case to all elements of the mobility system. The system would be composed of satellites in various orbits as well as fiberoptic nets. Available information should include, for example: surveillance/reconnaissance, command and control (C2), combat identification, communications/computer nets, intelligence, weather and precision navigation.

In-transit visibility of aircraft cargo, passengers and patients is another benefit. This must be accomplished in a seamless DoD transportation system consisting of sub-systems that not only communicate with each other but with system-supporting civilian entities to include the Civil Reserve Air Fleet. The global network must contain a sub-network core that is totally reliable and protected in warfighting situations, connects aerospace vehicles (manned and unmanned) with command nodes and employs embedded computation with trusted fusion capability. Terrestrial (fiberoptic, optical, wireless) and satellite communication architectures will be necessary.

Near-perfect real-time situational awareness provided to the aircrew is another plus. Relevant information should include for example: threat updates, weather, airfield information (delays, base loading, fuel availability, runway composition etc.) and air refueling rendezvous data/offload. Accurate and timely intelligence information not only aids preflight planning but must be tailored to specific mission needs ranging from humanitarian relief, to a ground threat situation update for an airborne unit prior to paradrop.

The vision is assured communications connectivity coupled with providing the right information to the right person at the right time. To accomplish this, timely, automated direct-feed collection and fusion, improved imaging intelligence and multi-level security technology is

required. Information from cyberspace provided through globally connected computer networks is central to meet the warfare acceleration of the next century. Command and control assistance provided by computer-generated-automated planning/decision tools is imperative to enhance mobility force efficiency.

Information dominance must include the technological ability to conduct C^2 Warfare by denying any adversary the ability to paralyze or exploit the information spectrum, thereby insuring preservation of the tactical initiative. Conversely, interfering with the adversary's decision process is a needed military capability.

The above-mentioned capabilities must always be measured against the constants of affordability, survivability, supportability, mobility, commonality, interoperability, standardization, and user friendliness while exploiting commercial off-the-shelf technologies.

Promising technologies that require exploitation to satisfy the requirements stated above include integration of national/airborne/commercial surveillance resources, integration of the wired/wireless global grid, core bitways (ground/sea/air) and services, automatic coordination, data fusion and planning applications, small massive parallel processors and multi-level security/access applications. There must be both doctrinal and technological advancement.

Worldwide communications will increase mobility efficiency by providing instantaneous connectivity, quick problem resolution and greater C^2 flexibility. Also, it will make available much needed in-transit visibility and situational awareness.

4.4 Wing in Ground Effect (WIG) Transport

WIG aircraft rely on the increased lift generated by an airfoil moving over a surface at very low altitudes (generally not exceeding one chord length). Fuel economy is increased by as much as five times. This effect rises steeply at altitudes less than 1/10 of the wing span, so practical transport systems relying on WIG are very large, with cruise heights of 10-20 feet, largely limiting them to over-water operation. One current concept (Figure 4.4-1) transports 250,000 pounds of cargo over 6,000 miles at 400 to 450 knots. Other versions have been designed to carry payloads up to five million pounds - equivalent to forty C-141 loads or fifteen C-5 loads.

Benefits

WIG aircraft provide a high speed air supplement to the sealift component of the mobility triad (air, land, and sea). WIG aircraft provide true fast sea-based lift capability,with flexible terminal options. Speed is ten times that of the fastest transport ships. WIGs can load and unload at virtually any location on water and can fly over land at altitudes up to several thousand feet (although less efficiently) to land at aerial ports. Speed and water landing capability supplement prepositioning for sustainment in sea-based airlift during expeditionary, over-the-shore, and littoral operations.

Technology Needs

Low-drag hulls, cargo transfer system for water-based operations, saltwater corrosion protection, obstacle detection and collision avoidance, propulsion (including takeoff lift augmentation), as well as research on effects of sea state and weather on lift and control feasibility.

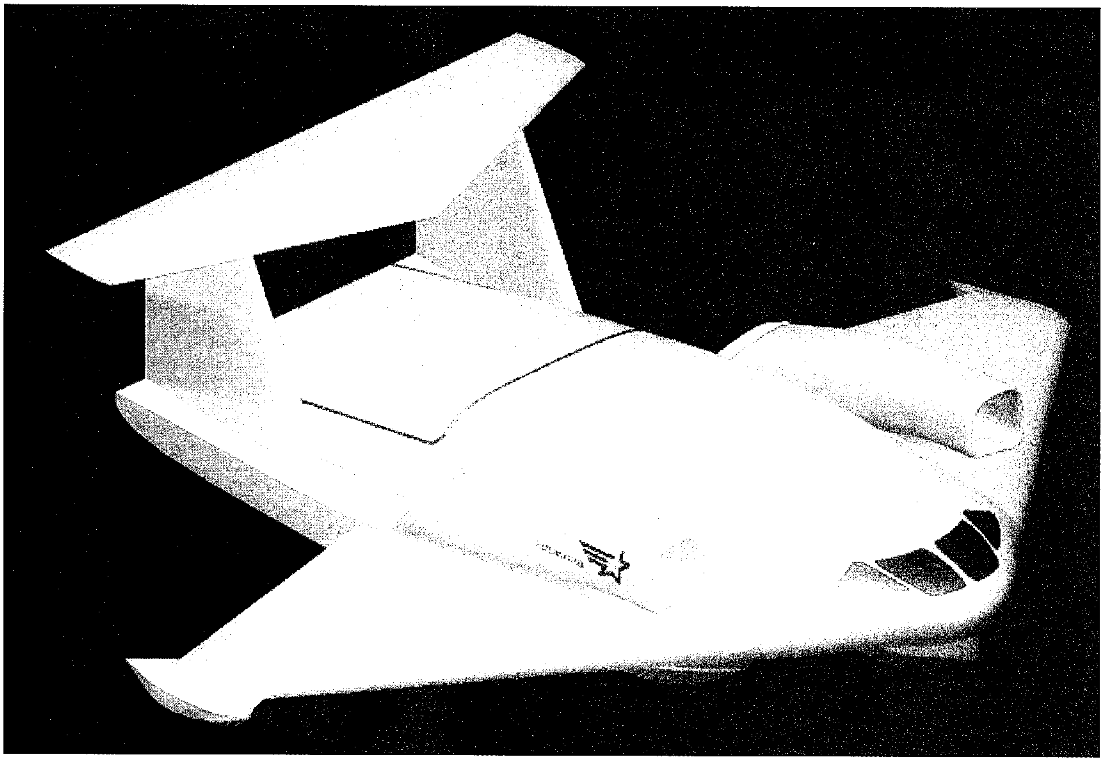

Figure 4.4-1 Wing in Ground Effect Transport Concept

4.5 Global Navigation System

A navigation system for aircraft operating anywhere in the world with an accuracy of one meter is envisioned based upon geostationary satellites, advanced communication networks, and enhanced computer capability. This will greatly improve economics and safety for all mobility missions.

Benefits

It will be technically possible to control the world's air traffic from eight centers—both enroute and on approach. Tests to demonstrate the feasibility of controlling aircraft enroute in remote areas or over the oceans have been conducted. Pilot's radio reports of position to ground controllers, which take from 5 to 45 minutes, can be eliminated. Uncertainty of position, which means the 20 minutes or 15,000 square mile safety zone, could be reduced over some routes. Choke points could be minimized to triple capacity and shorten delays into major air hubs. Digitized radio transmissions could streamline communication between the flight computer on board and the air traffic control computer located on the ground. One benefit is the reduced fuel burn and flight time by optimizing flight plans for different weather conditions. A second benefit is to lessen spacing and increase the capacity of crowded skies. The navigation and communication tools would allow the AMC fleet to fly direct, take advantage of winds, not be constrained

by altitude and speed, and avoid delays getting into the airspace to increase mission effectiveness.

Technology Needs

The Air Force should take a leadership role in advocating the use of the global navigation system as the international enroute and landing approach solution. Augmented GPS signals can provide the accuracy, integrity, availability and continuity for precision approaches. A decision on the method to communicate the data through a satellite data link is necessary to enable many aircraft to communicate their GPS positions to one another and to ground stations. This has particular significance for the mobility mission, particularly reducing the need for radio communication. Anomalies in the signal pattern and jamming susceptibility must be completely understood and mitigated to give full confidence to the international user.

4.6 Advanced Material Handling Equipment

Currently, the positioning of material handling equipment (MHE) by airlift to global destinations presents a heavy demand on early airlift capacity. Further, the on-ground mobility of the current MHE fleet is inadequate for current and future needs.

Marginal ideas such as magnetic levitation were discussed as potential solutions to the problem of loading and unloading transports (particularly commercial derivatives). No realistic potential solution was uncovered, the need persists.

Benefits

If a new system could be invented, it would reduce the number of airlift loads required and improve cargo delivery times particularly in the early days of a conflict.

Technology Needs

No technology demonstration programs exist to reduce dependence on MHE. USAF Wright Laboratories is contemplating an Improved Methods for Airlift Cargo Handling (IMACH) demonstration program. Joint Force Power Group is engaged in a first step - identifying common cargo handling concepts. New technology concepts are needed to support the mobility mission.

4.7 Precision/Large Scale Airdrop

More robust airdrop systems enable broader use of airdrop instead of airland operations for rapid force insertion and direct delivery while providing increased aircraft/air crew survivability. This capability comprises two components: new or improved airdrop systems (ADS) and improvements to aircraft equipment used to perform airdrop. Precision airdrop technology increases the mission success rate of cargo airdrop. New airdrop systems (ADS) extend airdrop to larger loads, higher altitudes, and substantial standoff. Enhancements to airdrop attack all components of the air delivery error budget, benefiting directly from the development and testing of precision munitions delivery systems. Widespread use of GPS means both intended impact point and aircraft position are known within the accuracy of GPS-based techniques. GPS

leads to highly reliable "drop on coordinates" capability. Ballistic winds measurement using dropsondes or LIDAR reduce uncertainty by providing wind models to simulation of trajectory.

Benefits

The greatest advantage of precision airdrop is the greater survivability of aircraft and aircrews afforded by high altitude and long standoff releases. Another direct benefit would be a broader use of airdrop for rapid force insertion and direct delivery. Also, precision delivery of material would lead to wider use of airdrop. Highly mobile forces would be more economically supported with large scale airdrop than by building temporary air bases. Extension of precision cargo drop technology to paratroop operations would lead to use of smaller drop zones and more immediate ground force battle readiness.

Technology Needs

New airborne sensors and offboard imagery and targeting data feeds establish accurate slant ranges in the absence of GPS, or can be used in concert to refine location accuracy. Development of higher load-carrying parasails is needed, lower cost devices are desired. Precision airdrop of paratroopers depends upon a new paratrooper guidance system.

4.8 Virtual Reality Training

By combining computer-generated imagery with advanced three-dimensional holographic displays, simulators can be constructed for almost all air mobility functions. The first application could be for flight simulators (some motion cues may also be required). Similar software could be generated for maintenance training and operational training (such as loading and unloading the transport). Refueling operations could also be simulated. Once the software, computer systems and displays were available they could also be used to evaluate different operational procedures. A major advance will be the combining of these simulators through secure datalinks to other services and remote locations. Thus networked simulation training will be possible. With adequate data links crews could be prepared to fly into very austere fields and better understand their full missions. Rehearsal training will be very realistic.

Benefits

One big advantage of the system would be in keeping up with configuration and operational changes. These would be in software rather than in hardware. Another advantage will be in increased realism. These applications should result in reduced training costs and improved efficiencies for all mobility missions.

Technology Needs

Development of these concepts should be in parallel with many similar commercial projects. This shared costing for the development is a distinct possibility.

The technology developments required are: higher definition, three-dimensional holographic displays, advanced computer-generated 3D imagery, and high speed (parallel processing) computer power to integrate all these elements.

4.9 Directed Energy Self-Defense System

This system is proposed for large air mobility-sized aircraft, and would encompass the use of a missile attack warning system to alert a directed energy (i.e. a laser, high-power microwave (HPM)), or Self-Protection Missile (SPM) to destroy or confuse an approaching missile.

Surface-to-air, or air-to-air missiles, are a major threat to mobility aircraft performing cargo airlift, passenger airlift, airdrop operations, medical evacuation, special operations and refueling missions. The proliferation of these missiles gives hostile nations and unfriendly faction groups an opportunity to employ weapons against air mobility aircraft, who on a routine basis, use the world's airfields. Threats range from handheld ground-launched IR missiles to SAMs and fighter-launched missiles. Mobility aircraft must have warning of an impending attack through: Real-Time-in-Cockpit (RTIC) situation awareness system; on-aircraft passive/active missile approach warning sensors; and, systems that defeats approaching missiles. A directed energy defensive system would enhance air mobility-sized aircraft's survivability substantially and provide assurances of primary mission success.

Approach

1. The development of a sensor(s) system to ensure spherical (4 pi steradian) coverage around the aircraft which alerts the crew when under attack and defines a relatively accurate azimuth resolution track file for counter missile activity.
2. The employment of high speed computation to provide a fine resolution pointer-tracker to precisely orient an on-board directed energy counter measure system at approaching missiles.
3. The development of a directed energy (laser/high power microwave) counter measure system capable of engaging (destroying or confusing) an approaching missile at sufficient range to ensure protection of the host aircraft. Also, under consideration is a SPM with either a HPM or small warhead.

Missile warning systems have been developed that provide relatively good azimuth and range information for RF acquisition and tracking systems. However, missile warning systems for IR-guided, ground and air-launched missiles, is sorely lacking. Two recent USAF/Navy programs attempted to address this shortfall. Both the Missile Attack Warning System (MAWS) and Silent Attack Warning (SAW) systems both focused on the IR missile threat, but have not matured due to insufficient funding. The Advanced Threat IR Counter Measure (ATIRCM) program is the latest joint initiative to solve the IR missile warning problem. This Army-led program inherited the MAWS program and schedule. However, to keep people on their toes they renamed it Common Missile Warning System (CMWS). The contractors bidding for the ATIRCM/CMWS contract may propose full coverage IR search air track (IRST) sensor systems, single or array detector systems, UV, MMW and other sensor ideas that will acquire and track incoming IR (or other passive seeker) missiles.

Correspondingly, massively parallel computing processors begin to offer the capability needed to predict an on-coming missiles' flight trajectory and impact points. Next generation fast computing will be required to solve the difficult pointing and tracking problem for a directed energy defensive system to be successful. As this capability is developed countermeasure

system can be employed to confuse or destroy threat missiles. Flares and decoys are of some value, but offering the most promise are the following three initiatives:

1. A laser weapon that is both adequately lethal and sufficiently compact to be practical as a self-defense weapon. The laser would be located so that it has full coverage of both hemispheres around the aircraft. The power requirements should be reasonable and consistent with what the airplane can supply. A potential lightweight system operates at the kilojoule laser level.
2. A high-power microwave system that is capable of destroying an attacking missile without degrading the aircraft's basic mission is another option. However, the problem of degrading the basic mission is severe.
3. A small Self-Protection Missile (SPM) capable of intercepting an approaching missile.

Benefits

A directed energy system would provide active protection for air mobility aircraft. Since they are not able to take evasive action, an active system is needed. The transports have much more space and power available than tactical aircraft and hence it is more feasible.

Continued technology developments of on-board missile sensors and computers must continue to support the concept. Also, the small laser system technology needs to continue with special emphasis toward accomodating a complete system within the weight, space, and power requirements of air mobility aircraft.

4.10 Unmanned Transport

This concept involves using modern control technology together with worldwide communications to eliminate the transport crew. It would be most practical when used as a flight of several transports where one had a pilot, copilot and loadmaster and the other craft were slaved to the lead ship. He would remotely land each before landing his own vehicle, or ground control of the landing could be done by telepresence. This concept would be initially applicable to cargo airlift, but with additional development could be applied to airdrop operations.

Benefits

Flight personnel are expensive and vulnerable. The number of flight personnel at risk and in total would be reduced.

Technical Needs

Major technology advances in reliability are required in all aircraft systems, particularly controls. In addition, secure, dependable communications are required.

4.11 Containerized, Intermodal System

Economical long haul cargo transport using surface transportation modes (truck, rail, or ship) increasingly relies on packaging of cargo into standard intermodal containers that are transferred from one mode to another. The container is only "broken" at its destination or a

planned redistribution point. Today, military cargo transportation needs are increasingly being met through intermodal containerization to take advantage of the cost economies and distribution system available using commercial carriers and equipment. Many military trucks and ships differ from their commercial counterparts only in ownership. Intermodal ports have an air component enabling direct transfer of standard containers between surface and air transportation systems.

Benefits

Adding an intermodal dimension to air cargo capabilities facilitates both rapid deployment and readiness. The intermodal system for air mobility (ISAM) concept recognizes the integral character of airlift in the mobility triad (air, land, and sea) by inserting container handling capability into aircraft material handling systems.

Many studies of intermodal freight emphasized potential commercial applications of military airlift aircraft. Now, the emphasis is just the reverse - exploiting commercialintermodal technology to improve military airlift. One of the foremost limiting factors turned out to be the inherent difference between the Air Force's 463L cargo handling system and the International Standards Organization (ISO) intermodal container configuration standard. No common interfaces exist between 463L pallets and ISO containers, meaning additional port and material handling equipment is needed to transfer cargo to and from transport aircraft.

In the 1970's, Project INTACT Intermodal Air Cargo Test culminated in the first practical demonstration of complete intermodal compatibility between air and surface freight transportation. The program evolved from the consensus that an expanded air cargo fleet would meet the need to enable air freight to evolve from a premium specialty service keyed to small shipments to an economical prime large-volume distribution service. Project INTACT showed that large, advanced technology aircraft would provide an economical air component for container-based intermodal transport.

Tomorrow's transportation network must recognize the interlocking relationships of the mobility triad: airlift, sealift, and overland transportation. Adapting air cargo to include intermodal containers emphasizes total distribution system economies. Although containers contribute higher tare weights than palletized (breakbulk), the advantage comes in the form of end-to-end distribution economies - reductions in manpower and equipment needed for transfer between air and surface modes of transport.

Technology Needs

Aircraft and cargo tracking (point of sale) system inputs for container identification systems, aircraft-compatible intermodal (container transfer) material handling equipment.

4.12 Rocket Transport

The system envisages accurate delivery of non-explosive payload by rocket from US bases to points around the globe. The system would complement existing payload delivery systems of Air Mobility Command for extremely high priority items.

The challenges to developing a viable system are numerous:

1. Limited volume and weight of payload
2. Requires modular payload compartments, preferably preloaded, for rapid attachment to rocket.
3. Reentry heat protection for a relatively large payload compartment will impact payload.
4. Specific payload compartment shape required for stability during reentry may impact volumetric efficiency.
5. Requires programmed rocket ready to fire as soon as payload module is in place.
6. Final reentry - soft landing stage - would be the least accurate phase of delivery if parachutes were necessary. Retro-rockets would improve accuracy. Work is needed to evaluate the payload penalties involved.
7. Feasibility of a shock-absorbing target area in selected areas overseas would reduce payload penalties if higher impact velocity could be tolerated. Research would be required. Use of such technologies would reduce the number of delivery points worldwide, and raises the competitive concept of pre-positioned stockpiles.
8. Local mapping of delivery points needs to be compatible with global coordinate system.

Benefits

1. Very short transit time - under one hour to any location worldwide. A two hour order to receipt may be feasible.
2. High accuracy of delivery.
3. Valuable as means of delivering extremely high priority items.

Technical Needs

1. Technical assessment to evaluate the points raised in the technical assessment above. Initial study on net weight and net volumetric capacities practicable as add-ons to existing solid fuel rockets such as Titan and Minuteman. Weight and volumetric studies should include initial feasibility design of stable reentry freight compartment with reentry heat protection.
2. Determination of demand for system on basis of outcome of 1.
3. Review of 1 and 2. Determination of need and decision on next step.

4.13 Air Refueling Transfer Craft (ARTCraft)

The ARTCraft concept is unmanned high-speed air vehicles that fill with fuel from a tanker "mothership," then fly out to refuel fighters at higher speeds while flying with the receiver aircraft (fighter), then return to the mothership. Each would contain enough fuel to enable loiter, flight, and recovery in addition to that required to refuel one fighter. Multiple ARTCraft would operate with each mothership, say up to 20, where command and control (C^2) is based.

C^2 would also be shared among motherships, fighters, and theater C^2 air assets. Fuel transfer can be accomplished with conventional "probe and drogue" or receptacle systems or, for future systems, by actual attachment to the receiver. In the latter configuration, a high rate transfer system would enable minimum flight time in the refueling configuration but also allow maneuver while mated. This could be as simple as a "married" control system to enable two craft to fly as one. More aircraft could be refueled at one time, over a wider area and at a range of altitudes. ARTCraft could either be deployed from the mothership or fly together with it.

Benefits

ARTCraft could support the Air Refueling mission area, including all key processes within the mission area.

The use of multiple autonomous fuel transfer craft enables as many fighters to be refueled simultaneously from a single tanker as there are ARTCraft associated with it. Refueling takes place at fighter cruise speeds, rather than tanker speeds. The aircraft are refueled at a distance from the tanker.

Technology Needs

Unmanned air vehicle guidance and control, coordinated control systems, high rate fuel transfer.

4.14 Stealth Transport

The need for special operations is envisioned to dramatically increase in the future. Vulnerability of airlift aircraft presents a constantly growing weakness of mobility operations in hostile areas. All transport aircraft are vulnerable to proliferating low-cost hand-held IR missiles. Tactical and special operations transports must face even higher threats from air defense radar and other sensor systems, as well as small arms fire. The Special Operations Command has a long recognized need for a low-observable transport aircraft, reflected in a Mission Need Statement.

Rapid advances in stealth made in fighter and bomber aircraft have not been implemented in the transport community. Today's special operations workhorses, the MC-130, AC-130, MH-53J and MH-60G fall short of SOCOM mission needs. The Air Force's newest airlifter, the C-17, began development prior to the recognition of the need and capability to implement stealth. Today, transport aircraft can be readily developed that feature low observables and a broad range of other survivability enhancements.

Benefits

A survivable transport, well-suited to forward tactical transport missions, will directly benefit from stealth technology now in the fighter community, including geometric shaping, composite structures, and radar-absorbing materials. In addition, integrated propulsive high-lift systems meet the demand for short-field operations. Survivable transports also benefit from built-in defensive systems and use of off-board navigation and information data feeds, including all-weather operations.

Technology Needs

Affordability is the key issue due to the small quantity of aircraft needed to meet Air Force theater lift capacity. Although commercial aircraft and derivatives thereof also require survivability improvements, aircraft capable of operating in high-threat environments pose a military-specific need. A new military acquisition would be needed.

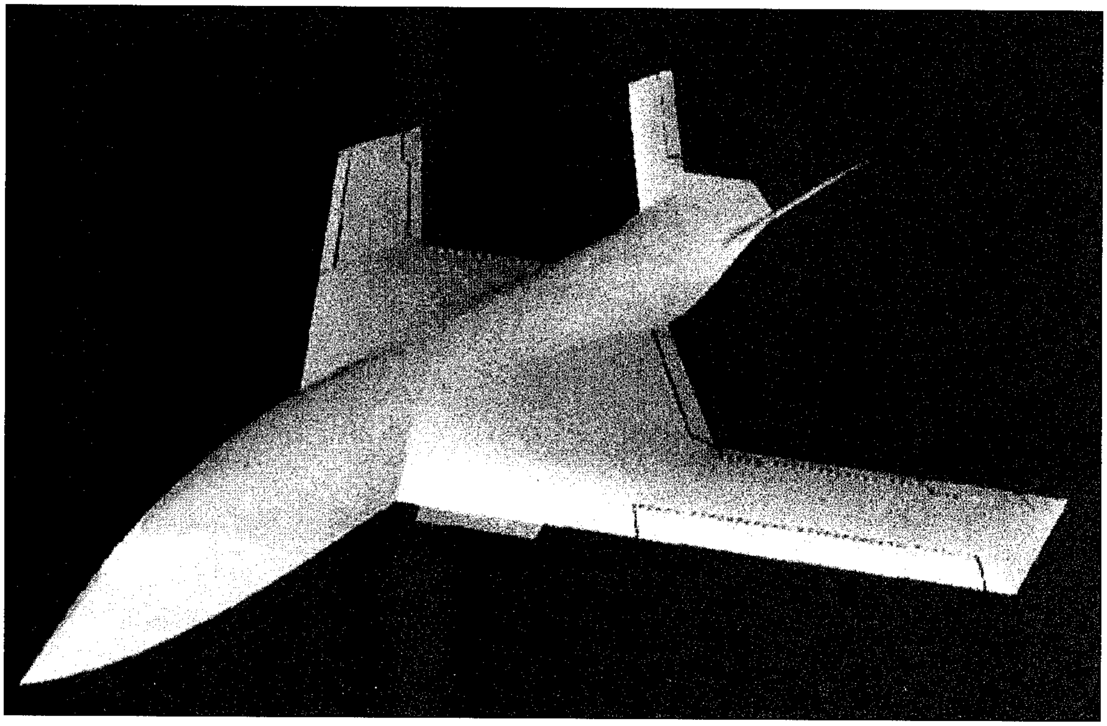

Figure 4.14-1 Stealth Transport Concept

4.15 Twin Fuselage Aircraft

Concept

The concept advanced here is that of an airplane configuration having twin fuselages that are separated by straight wing and tail surfaces. The underlying problem being addressed is that of finding a way to increase the wing aspect ratio of an airframe without incurring the associated structural weight penalties. and at the same time to realize the increased L/D (lift over drag) benefits that higher aspect ratios provide.

In the analysis of airplane performance from a range and payload point of view, three fundamental parameters appear, namely: zero lift drag coefficient (C_{do}) specific fuel consumption (c) and wing aspect ratio (AR). To obtain good range, (or low fuel consumption) the aim is to keep C_{do} and c small, and AR large. Much has been done to make the airplane clean (that is to make C_{do} small) and much has been done to reduce the specific fuel consumption of the engines. Practical design considerations, however, constrain the desire to have large aspect ratios. For

the conventional type airplane configurations - those with a single fuselage - wing bending moment increases dramatically with aspect ratio, and causes the wing weight to grow excessively, precluding a more practical design. As a result, aspect ratio in conventional design has been generally limited to the 7 to 9 range.

Benefits

The use of a twin or dual fuselage configuration is a way that aspect ratios can be increased. This arrangement allows a dramatic reduction of wing bending moment, hence a way to achieve lower wing weights while obtaining high aspect ratios. Analysis indicates, for example, that an aspect ratio of 12 can be obtained with a wing weight less than that of a conventional design. At the same time a synergistic improvement is found throughout the airframe design:

1. The fuel consumption is lowered.
2. The skin friction area of a twin fuselage configuration may be less than a corresponding single fuselage design.
3. The gross weight, engine thrust requirements and airplane size are reduced.
4. Aeroelastic effects are reduced.
5. The flap system may be simplified.

The resulting payoff offered by the twin-fuselage concept can be seen by the typical results shown in Table 4.15-1. Values are given for a base or reference configuration, and for

Table 4.15-1. Comparison of Single vs Twin Fuselage

Number of Passengers = 300 *Range = 6000 nautical miles*		Gross Weight	Total Max Engine Thrust	Wing Area	Wing Span	Seat-miles per pound
Base	Single	652,700	145,400	6101	214	7.21
	Twin	499,100	113,000	4596	224	10.64 +47.6%
With -10%c	Single	555,900	128,600	5009	194	8.95
	Twin	444,400	103,600	3971	209	12.72 +42.1%
With -10%W	Single	523,500	119,400	4783	189	8.83
	Twin	489,400	96,400	3800	204	12.49 +41.4%

technology reductions in specific fuel consumption and for structure weight, considered separately. The configuration parameters, gross weight, engine thrust required, and wing area, are all noted to be decreased in the range of 20% for the twin concept relative to the single fuselage configuration. The basic operational parameter, seat-miles per pound of fuel, as given by the right-column numbers, is noted to increase by a remarkable 40-50%, further indicating the marked gains to be realized by the twin-fuselage concept.

Technology Needs

Items to consider include: landing gear tread, ground handling and turning and pilot offset. Developments needed include wind tunnel tests to verify L/D increase, proceed with a prototype to gain operational experience (note: construction can proceed by simply applying present day technology and assembly processes).

4.16 Modular Transport Aircraft

The key to achieving dramatic improvements in airlift efficiency may still be achieved by exploring innovative new concepts. The modular airlifter illustrates this potential in a concept that combines aspects of mobility operations and innovative aircraft concepts of the past with deliberate investment in new technology.

The modular airlifter attempts to create an aircraft system analogous to surface modes of transport, such as trains or barges, by linking multiple cargo mobilizing units (boxcars) together to achieve efficiencies not available to separate air vehicles. However, rather than separate the locomotive source from the cargo units, the air train joins multiple, otherwise independent aircraft wingtip to wingtip, achieving higher combined efficiency by reducing drag due to tip losses and exploiting the aerodynamic benefit of high aspect ratio. The units take off under their own power, then maneuver into position once aloft and complete a connection at the wingtip during steady climb or once cruise altitude and speed have been established. The connection may be mechanical or electromagnetic. The joint transfers sufficient load to hold the air train together in its joined configuration, yet separates under sudden application of large load excursions.

One concept of the modular airlifter exploits a span loading all-wing shape and integrated propulsive lift shown in Figure 4.16-1. The engine is buried within the airfoil shape and draws air through a spanwise slot inlet to augment circulation lift and maintain laminar flow, achieving high lift-to-drag and permitting use of a very high thickness ratio. A 100 foot span and a 40-50 foot chord encompasses a cargo compartment able to carry four 20' ISO containers, weighing up to 200,000 pounds, with sufficient thickness behind the rear beam for four transversely mounted engines with a fan diameter of more than 8 feet. The engines exhaust through a full-span, vectoring trailing edge jet flap.

Benefits

Unprecedented advantages can be gained. A modular airlifter comprising six units as in Figure 4.16-2 attains an aspect ratio of 24, carries 1.2 million pounds, and weighs 3 million pounds, yet operates from the same airfields as a C-130 or C-17. The all-wing shape doubles the maximum number of aircraft on the ground (MOG), quadrupling throughput. Laminar flow and

possible elimination of tail surfaces reduce drag. Structural weight is minimized by achievement of high volumetric efficiency, minimizing the fuselage, and high section properties. Sophisticated automatic flight control, tightly linked among all units, enables operation with a much reduced crew complement. Possibly, only one unit would be manned, with the others operated under supervised autonomy.

Operationally, a modular airlifter can be assembled from multiple aircraft departing from geographically dispersed air ports of embarkation, fly together for efficient long range cruise, then deliver to one or multiple air ports of debarkation.

Technology Needs

Key technologies include integrated propulsive lift, transverse propulsion systems, in-flight coupling and coupled flight, atmospheric monitoring systems, and robust autonomous control.

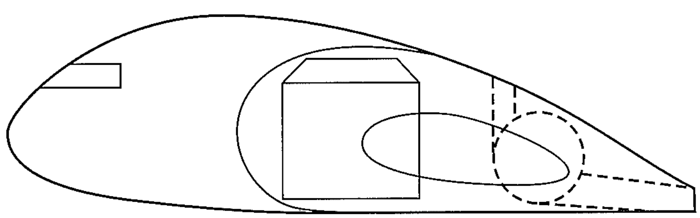

Figure 4.16-1 Span Loading Wing Design

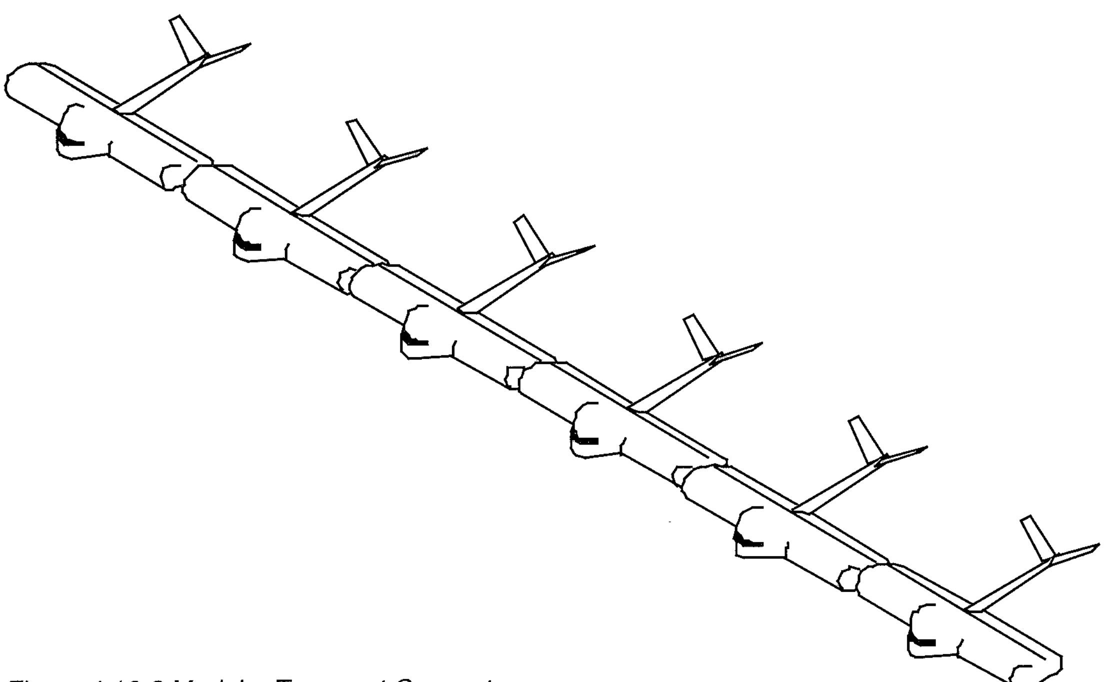

Figure 4.16-2 Modular Transport Concept

4.17 Improved Refueling System

A key element in the ability of the US Air Force to provide Global Reach is the Air Mobility Command tanker force. Aerial refueling is essential to rapid world-wide force projection. Operational requirements frequently demand rapid fuel off-load to multiple receivers. At this time, only two methods are available for fuel transfer, boom/receptacle or probe/drogue. Each of these options has drawbacks. Boom refueling provides a higher fuel transfer rate but is limited to one receiver aircraft per tanker, which impacts critical target timing for large fighter strike packages. Drogue refueling permits two receiver aircraft per tanker, however, off-load transfer rate is reduced. Tanker/refueling system limitations are but one part of the fuel transfer equation. Fighter aircraft internal fuel systems are limited in size due to fighter dimensions and constrain receiver on-load rates. Further, only US Navy fighter aircraft are probe-equipped and therefore compatible with drogue-equipped tanker aircraft.

This situation logically leads to the question of whether some technically improved refueling system can be devised that is compatible with existing multi-service aircraft configurations and will satisfy the operational requirements of rapid off-load to multiple receivers.

A review of technological opportunities to find such a concept proved unsuccessful. The realistic improvements would appear to involve improved boom control systems and remote boom operators. The remote boom operator could be extended to telepresence so that the crew size could be reduced. A better control system would result in a larger breakaway envelope and hence fewer inadvertent disconnects - resulting in shorter and safer refueling.

Continued technical development of advanced control concepts is required to expand the boom envelope. Virtual reality developments with displays, computer controls and sensors will be needed for the remote boom operator. The development of a remote boom operator station will make it possible to develop and install pod-mounted refueling booms for large tankers. There are other developments needed in station-keeping, sensory, etc to permit true all-weather refueling.

Refueling of small aircraft takes too long. Efforts should continue to get higher pressure systems with higher flow rates.

4.18 VTOL Special Operations

Variable bypass engines can be developed in the near future which provide high thrust to weight for vertical takeoff and landing and also provide efficient cruise performance for transport aircraft. This concept would utilize such engines to power a small transport to support special operations. It could also be used for search and rescue. The vehicle would be capable of carrying a squad of troops for 500 to 1000 miles and then effecting a vertical landing to insert the troops. After insertion it would take-off vertically and return to its base. It could also be used for search and rescue and would have a hover capability as well.

Benefits

The primary benefits from such a system would be: 1) ability to operate into very small spaces, 2) faster insertion and recovery and 3) reduced vulnerability due to higher to higher cruise speeds (than helicopters).

Technology Needs

The technical challenges for this concept are formidable. Low cost composite materials are needed to keep the airframe weight low. Development of a variable by-pass engine with very high thrust to weight ratio (15:1) is required. It should have a cruise specific fuel consumption no higher than today's commercial transports. It is assumed that the technology for stability and control functions will be minor extensions of stability augmentation systems which exists today.

4.19 Sea Based Transport

Sea-based airlift could enhance force projection in the future. The USMC is exploring new operational concepts that dramatically reduce the "footprint" of expeditionary forces by airlifting 8'x8'x20' containers from a new series of combat service support team ships to inland 900'x50' landing zones. These new ships are envisioned to provide decks that accomodate airlift aircraft takeoffs and landings.

Sea based airlift relies on aircraft operating from water to perform air mobility operations. Aircraft concepts include those confined to takeoff and landing on water (seaplanes), those that can operate on either water or land (amphibians), or those that can operate from the deck of specially configured ships or floating air bases. Prepositioned materiel is transferred from the prepo ship to aircraft which then transport the cargo over the shore for airland or airdrop delivery.

One concept of sea-based airlift adapts the C-130 by attaching floats (Figure 4.19-1), retaining 23,000 to 25,000 pounds payload capacity. Advances in hydrodynamics leading to new hull and float designs promise to enable a renaissance of new seaplanes. Alternatively, aircraft with short takeoff and landing capability can operate from ships configured with decks shorter than 1,000 feet. A new, Super-Short TakeOff and Landing (SSTOL) aircraft will be needed to fulfill this role. USAF studies in the 1980's concluded that a tilt-wing medium transport could best achieve this needed performance. While seaplanes and amphibians may operate in weather up to sea state 3, the ability to transfer cargo to and from the aircraft is made more difficult.

Benefits

Sea-based deployment supports rapid response and rapid force projection using float prepositioning of equipment and supplies. Many potential regional and contingency conflicts occur within easy reach by air of coastal continental boundaries. Though aimed at cargo airlift, sea based airlift conceivably can perform a broad range of airlift and air refueling missions in conjunction with suitably configured ships or land-based facilities. Sea-based airlift provides a forward air component of the land-sea-air mobility triad.

Sea based airlift increases the flexibility and range of air delivery options, speeds response by enabling prepositioning rather than CONUS basing, and reduces the land footprint of amphibious operations. This capability is especially attractive for special operations.

Technology Needs

Key technologies needed include: float and hull design (reduced drag and improved stability), stable ship-to-aircraft transfer systems, corrosion protection (especially salt-water), and large payload precision airdrop.

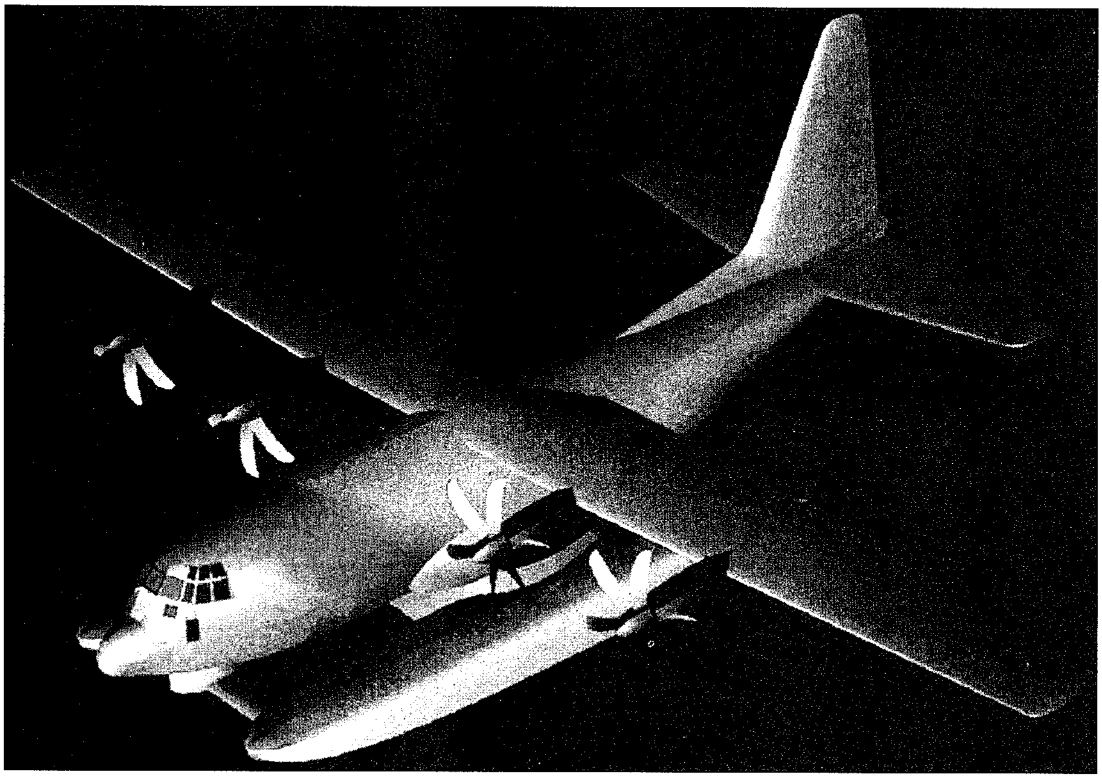

Figure 4.19-1 Sea Based Transport Concept

5.0 Evaluation of Future Systems and Ranking

Since the proposed concepts (Section 4) differ in approach, complexity, technical risk, and utility, a system to select the most promising was put in place. After referring to the charter (Appendix A) and much discussion among the panel members, it was agreed that the following items would be included in the evaluation:

A. Mobility Mission Enhancement
B. Supportability and Training
C. Affordability
D. Technology availability by 2020
E. Commercial development and dual use.

The following weighting was proposed:

A = 40%
B = 12%
C = 20%
D = 20%
E = 8%

All ten panel members made recommendations which were then averaged, yielding the following revised weighings:

A = 40%
B = 15%
C = 20%
D = 15%
E = 10%

Next, the panel members were asked to evaluate all the concepts of Section 4 using the final weightings and to provide their prioritized list. These lists were combined giving equal weight to each member's input. The results of this exercise are shown in Table 5.0-1.

Finally, a review of these results was conducted by the whole panel. This was a "sanity check" to make sure the right things were being exercised. As a result of this review it was decided to remove the Global Navigation System (GNS) concept since it was basically existing technology. There was agreement that GNS was vital to mobility missions and that we should support it. However, it was felt that GNS no longer qualified as revolutionary technology.

The evaluation put Virtual Reality Training as Number 4 and Directed Energy Self- Defense as Number 5. This was questioned by several members. It was agreed they should be reversed; but that the number of selected systems to be covered in detail (Section 6) should be set at five to include Virtual Reality. In addition, the Virtual Reality concept should be expanded to cover all applications rather than just training. The final rankings are shown in Table 5.0-2.

Table 5.0-1: Mobility Application Panel Topics - Voted Order

Original Order	Project	Sum	Avg	Variance	Median	Voted Priority
3	Information dominance system	19	1.90	.49	2.	1
1	Global range transport	31	3.10	5.49	2.5	2
7	Precision/large scale airdrop	53	5.30	8.21	4.	4
9	Directed energy defensive system	76	7.60	16.24	7.5	6
8	Virtual reality applications	71	7.10	23.69	5.	5
5	Global navigation system	49	4.90	13.09	5.	3
2	Supersonic military transport	78	7.80	11.16	7.5	7
11	Containerization, intermodal system	94	9.40	19.64	9.	8
17	Improved refueling system	96	9.60	14.84	8.5	9
15	Dual fuselage transport	101	10.10	14.69	9.5	10
6	Enhanced material handling equipment	109	10.90	33.09	7.5	11
18	VTOL special operations	111	11.10	4.49	12.	12
10	Unmanned transport	125	12.50	6.25	12.5	13
14	Stealth transport	133	13.30	18.01	14.5	14
19	Sea based transport	138	13.80	20.56	13.5	15
4	Wing in ground effect (WIG) transport	140	14.00	10.00	14.5	16
16	Modular transport aircraft	150	15.00	3.00	16.	17
13	Air refueling transfer craft	160	16.00	8.20	17.	18
12	Rocket transport	166	16.60	3.84	17.	19

Table 5.0-2: Final System Ranking

1	**Information dominance system**
2	**Global range transport**
3	**Precision/large scale airdrop**
4	**Directed energy self-defense system**
5	**Virtual reality applications**
6	**Supersonic military transport**
7	**Containerized, intermodal system**
8	**Improved refueling system**
9	**Twin fuselage transport**
10	**Advanced material handling equipment**
11	**VTOL special operations**
12	**Unmanned transport**
13	**Stealth transport**
14	**Sea-based transport**
15	**Wing in ground effect transport**
16	**Modular transport aircraft**
17	**Air refueling transfer craft**
18	**Rocket transport**

6.0 Selected Future Systems

The proposed systems introduced in Section 4 were discussed by the panel members and voted on, according to the evaluation described in Section 5. While reviewing the results of the evaluation, the panel decided, after much discussion, that the Global Navigation System (GNS) was really an existing technology (based on GPS). It was agreed that although it would not be presented as a selected system in this section, the need for greater accuracy and implementation of GNS in all mobility aircraft should be recognized.

Table 6.0-1: Selected Areas

1	**Information dominance system**
2	**Global range transport**
3	**Precision/large scale airdrop**
4	**Directed energy self-defense system**
5	**Virtual reality applications**

Based upon the results of the voting and further discussion by the panel, five of the listed future systems were selected as having the most potential to revolutionize the mobility mission in the future. The five selected areas are listed in Table 6.0-1 and discussed in Sections 6.1 through 6.5 in greater detail. Concepts expanded upon in these sections include benefits, affordability, commercial development potential, and technology requirements.

6.1 Information Dominance System

Background

Due to the worldwide nature of Air Mobility Command (AMC) missions and the wartime environment within which AMC must operate, reliable information systems must exist to operate and exercise command and control of the forces. AMC exercises C^2 over its forces through a global structure of fixed and deployed C^2 facilities supplemented by a 1990's communication network. These current and near future ground-based systems are supported by inefficient, limited-capacity processors and intelligence data systems, that are evolving through a merger of numerous federated legacy C^4I systems. Additionally, air mobility aircraft lack connectivity and the central computer processing necessary to provide accurate and timely information. They are stand-alone platform-centered designs that have not benefited from coordinated, and fused readily available information.

As a result, AMC faces a critical threat that affects the ability to conduct or complete assigned missions. Current C^4I systems are vulnerable to attack and lack most of the affordable security solutions that meet DoD's needs. Further, there exists a complete lack of assured instantaneous communication connectivity between the ground C^4I structure and AMC's airborne assets. AMC deficiencies in these areas include the following:

- Current C^4 architecture is inadequate to support global intransient visibility and C^2 requirements
- C^4S (systems) architecture is not in place to meet commercial compatibility
- AMC C^4 systems are not integrated nor meet "open systems" standards
- Air traffic control and landing system (ATCALS) equipment is lacking

- AMC C^2 system is incompatible with other command systems
- AMC has very limited worldwide communication with their assets
- The C^4 system lacks secure, surge, robust and flexible capability
- Existing deployable theater communication does not satisfy air mobility requirements
- AMC has no automated intelligence collection/requirements management system
- A poor capability exists for timely imagery receipt and exploitation
- The information warfare (IW) acquisition and implementation strategy is incomplete, no vulnerability assessment has been conducted.

Air Mobility Command is well aware of the importance of gaining information system dominance for their command's mission. They have written Mission Need Statements (AMC 023-93, CAF-AMC-AFSOC 311-92), Operational Requirements Documents (CAF 306-93-1), and developed an AMC C^4 system Master Plan. This plan recognizes five shortfalls:

- AMC's inability to access data when and where needed
- Inability to adapt to changing mission needs
- Inaccurate data
- Inability to share data across organizations
- Increased cost for hardware and software

Former AMC commander, and now USAF Chief of Staff, General Ronald Fogelman believes the 21st century offers a revolution in technology with many impressive capabilities emerging. He singled out "the exchange of information, and information warfare" as his first focus. He said "I see information having an ascending and transcending influence. Dominating the information spectrum is as critical to conflict now as occupying the land or controlling the air has been in the past. . . Information warfare may become the fifth dimension of warfare."

AMC has a major challenge to attain information systems dominance. However, the command has the senior officer emphasis and momentum to rapidly move into the information age.

Description

The revolution in information technology led by the US provides the Air Force an unequaled opportunity to exploit and seize the next vista in aerospace employment. The technology exists to develop, over the next 20 years, a system consisting of assured communications connectivity coupled with providing the right information to the right person at the right time.

The proposed AMC system should consist of worldwide communication networks that are secure and dependable. It should be a globally netted system with protected circuits and computers, that process fully automated fused intelligence and other on-demand information. This capability would be provided by interconnected satellites in various orbits as well as fiber optic ground nets. User-friendly information would flow from surveillance/reconnaissance, weather,

navigation and other information-gathering assets and be merged in fusion computers and provided to AMC's airborne and ground personnel. Near-perfect real-time situational awareness (SA) would be integrated seamlessly in the C^4I network. It would provide a comprehensive common tactical picture that included threat updates, airfield information, refueling rendezvous and other relevant mission data.

To obtain the above, AMC must develop Command specific C^4I architecture characteristics. For example, the AMC system should:

- Have access from any network terminal to and from all data and applications (authorized and need to know)
- Share software and hardware based on process vice organizational systems
- Shares common communications processors for all external access
- Share common logical data base
- Have a multi-level secure environment; and a protected core sub-system network that is totally reliable with trusted fusion capability
- Have a common high-speed multi-media transport utility

In 1995, the US Joint Chiefs of Staff made a commitment to the expanded Global Command and Control System (GCCS), global navigation grid, and an information strategy that would begin to insure information dominance systems in the 21st century. With connectivity to these global systems, operators at all levels would have on demand information concerning friendly and enemy force status and the current battle situation. Information would be two-way, on demand, distributed and interactive. It would be multi-source, from multiple sensors, multiple levels of display and aggregation, and tailored to the end user. AMC must ensure that Command unique requirements are integrated into these evolving systems. A core sub-system secure network that is reliable and protected for military information is needed. It should guarantee connections with command nodes and employ embedded computation with timed fusion capability. Finally, the system must ensure that it cannot be exploited through information warfare techniques and tactics.

Benefits

There will be increasing dependence on the GCCS and global navigation network services. AMC requires reliable information and intelligence products from these services, and the advantages of coordinated communications. The preferred capabilities of the future include services: between large airborne platforms, command posts and control centers; broadcast information from satellites, UAVs; connections between fighters/bombers, cruise missile/ATACMS, with airborne sensors and C^2 centers, and; high speed trunks for the collection and dissemination of aggregated large-volume traffic between ground control centers. This architecture provides deploying aircrews with high priority relevant information on demand for any airfield or location in the world. It will establish Real Time Information In the Cockpit (RTIC) operations as routine. The SAB Mobility Panel strongly supports an Information Dominance System for AMC operations.

Affordability

AMC has committed FYDP funds for many of the systems and capabilities included in this paper. However, the need to gain and maintain information dominance between now and the 21st century any additional funds requirements should be reviewed with a bias toward approval. Clearly, over the next 30 years, the information spectrum will occupy a pre-eminent position in all military activities.

Commercial Development Potential

The information explosion is being led by commercial development. Many of the capabilities that must be provided by a military global communications and control network are common with technological developments in commercial industry. For example, the basic computer work station and operating software systems. However attractive the potential for using commercial-off-the-shelf (COTS) systems may be, there still remains a number of unique military requirements that will demand tailored solutions with key existing and evolving COTS systems. These include: physical and electronic survivability (low-probability of detection and interception), anti-jam, data security and ultra-reliable message deliveries, on-demand multigigabit per second data flows in the commercial environment and wide bandwidth transmissions.

Nonetheless, commercial development remains very attractive in the information discipline. For example, opportunities exist involving the investments that will be made to modernize and standardize the military communication infrastructure, which is composed of numerous older systems. Because of the previous investments in these systems, a homogeneous communications system will evolve over a hybrid infrastructure. Commercial products should dominate this transition period.

Technology Requirements

During the last half of the 1990's a substantial technological commitment will be made developing the global command and control system. It is expected to replace the worldwide military command and control system (WWMCCS) in December 1995. The commitment to GCCS is expected to seamlessly integrate all services' C^4I systems in a worldwide network. It should give senior commanders near-real-time access to tactical data down to the level of the warfighter, and provide a solid system to expand from in the future.

As a result of the JCS strategy to pursue GCCS, the WWMCCS mainframe will be shut down and a new state-of-the-art commercial off-the-shelf client server system will be in use. This UNIX-based operating system will provide the framework for government computing for many years to come.

Technology developments will need to have progressed in computing speed, memory and data throughput in order to satisfy the demands of the global C^4I and navigation network of 2025. The vast amounts of data must be pushed unrestricted through seamless pipes, allowing high resolution (pixel) presentations on cooler active matrix liquid displays and terminals. Computer processing data flow software and other supporting technologies must grow.

It is imperative that AMC participate vigorously in the development of applicable technology to insure information dominance systems are available in 2025.

6.2 Global Range Transport

AMC Operational Objectives and Tasks

There are a number of technology advances that have the potential for revolutionizing airlift in the 2025 time frame. The development of an unrefueled global range transport becomes feasible, and has potentially attractive application to both commercial and military (AMC) missions. The resulting airlift capability will enhance AMC's ability to accomplish its operational objectives of power projection, force sustainment, and humanitarian or peacekeeping support throughout the world.

This section highlights the potential impact of several technology advances on the design of an unrefueled global range transport - with the associated benefits to AMC. Three key technologies of interest are:

- Improved propulsion efficiency (advanced engines based on improved materials, higher cycle temperatures and bypass ratios)
- Improved aerodynamic efficiency (advanced wing design and configurations)
- Light weight and low cost structure (including extensions of the present trends toward low-cost composites)
- Reorganized design and build of the airplane utilizing digital technology, teaming and flexible manufacturing

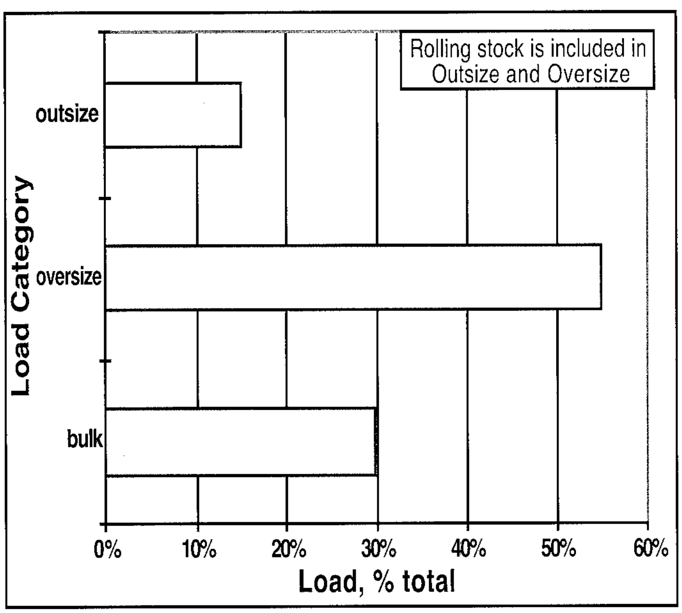

Figure 6.2-1, Air Mobility Command Cargo Categories

The global range transport that can result from these advances will revolutionize AMC's effectiveness.

Airlift

Cargo airlift - in combination with passenger airlift - is the backbone of the airlift task of AMC. Although the specific Mobility Operational Tasks - and the characterization of the associated cargo loads - for the 2025 and beyond time period cannot be known, for purposes of this section it is assumed that the cargo loads during the halting phase of a two nearly simultaneous major regional contingencies (2-MRC) scenario can be characterized as shown in Figure 6.2-1.

Note that only 15% of the projected cargo load must be transported on the C-5 or C-17 (i.e. only the outsize cargo). The remaining 85% of the projected load (bulk @ 30% and oversize @ 55%) can be transported on airplanes comparable to today's wide-body commercial transport airplanes.

CONUS Based Force Projection

The 2025 scenario of a primarily CONUS-based rapid power projection for establishing and reinforcing a US or multi-national presence will be strongly dependent on airlift for speed and flexibility in deploying, employing, and sustaining combat forces (ref Section 3). The world scene of 2025 will most likely include fewer staging and host nation support bases than were available to AMC during Desert Storm operations. Consequently, successful execution of AMC's tasks will require even greater dependence on air refueling, or an advanced transport with global range capability.

The development of an global range transport with an operational range of the order of 12,000 nm would dramatically enhance AMC's ability support a CONUS based force projection. Such airplanes would provide AMC global reach without requiring en-route refueling - thus freeing the tanker assets to support refueling of other airplanes of the combat force.

System Description

The development of transport airplanes have demonstrated a continuous increase in range factor since the initial jet transports, circa 1955. Figure 6.2-2 illustrates the history of range factor of wide body transports (range factor for long range cruise at optimum altitude) plotted as a function of the year of introduction of the specific airplane model. The most recent airplanes exhibit range factors in excess of 16,000 nm. The wide body airplanes are plotted with an open square symbol.

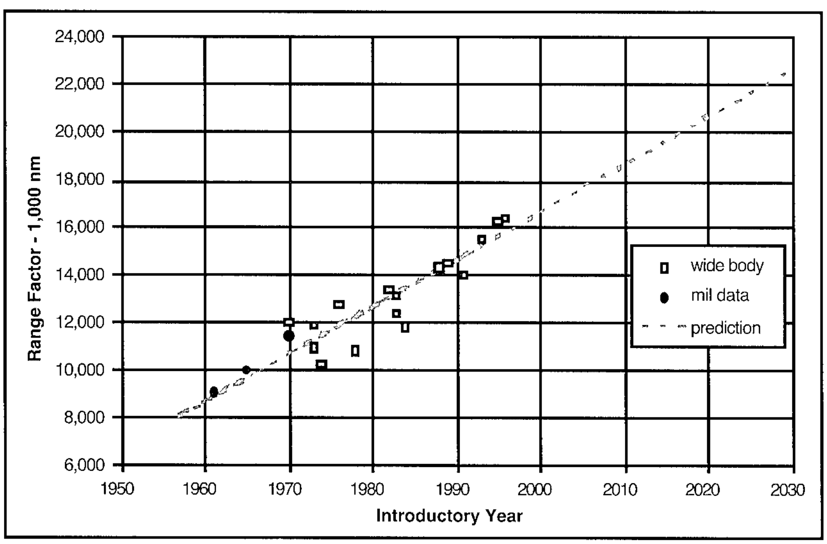

Figure 6.2-2, Predicted Range Factor Trend, Subsonic Jet Transports

The figure also shows three military transports (C-130, C-141, C-5 - plotted as filled circles) with their respective range factors varying from 9,000 nm to 11,500 nm (solid circles).

This trend suggests that a range factor of about 22,000 nm should be available circa 2025. Although this past 40 years progress obviously includes a number of unspecified technology advances,

an additional 10% improvement in range factor will become available from the identified technologies. Therefore, a range factor of 24,000 nm will be assumed for purposes of illustrating the resulting transport configuration.

Another factor in determining the range for a specific airplane is the empty weight fraction for a given payload. Figure 6.2-3 illustrates the trend data for commercial transports for the same time span as noted above. Presuming that a payload of 150,000 pounds is desirable for the global range transport, the trend suggests an OEW of about 400,000 lbs would be required. If there are further significant advances in the development of light weight structure, this OEW would be less than the trend line predicts. However, for purposes of this discussion, 400,000 will assumed.

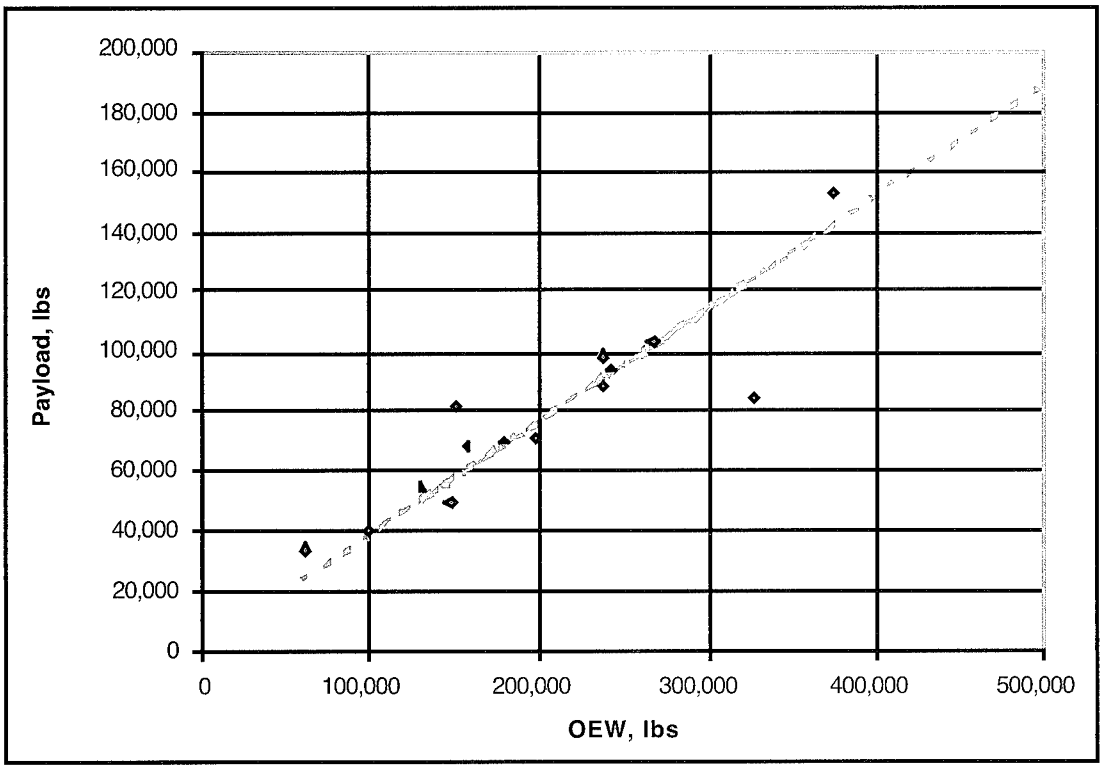

Figure 6.2-3 Payload vs OEW

In order to determine the gross weight characteristics of a global range transport, a family of take-off gross weight (TOGW) lines, plotted as a function of operating empty weight (OEW), for various constant range factors, are shown in Figure 6.2-4. Based on the previously described assumptions (150,000 lb. payload, 400,000 lb. OEW, 12,000 nm unrefueled range) the airplane TOGW will be about 900,000 lbs.

This is about 10% heavier than long range 747s that operate routinely at take-off gross weights (TOGWs) in excess of 800,000 lbs.

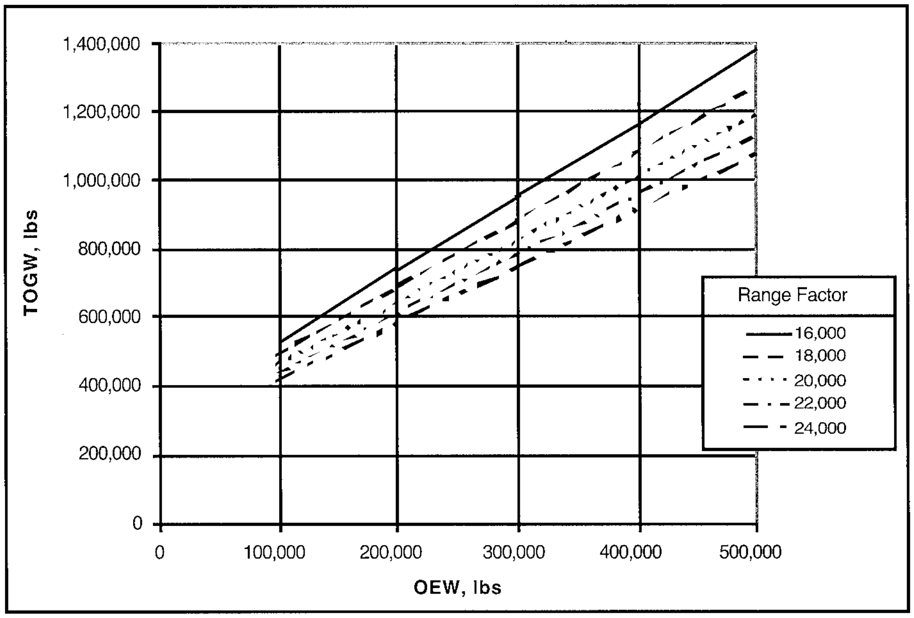

Figure 6.2-4 Effect of Range Factor on Global Range Airplane TOGW

Figure 6.2-5 shows the relative payload-range characteristics of the C-5, a 747, and this Global Range transport. Note that the take-off gross weight (TOGW) of the Global Range transport is not significantly greater than the 747-400.

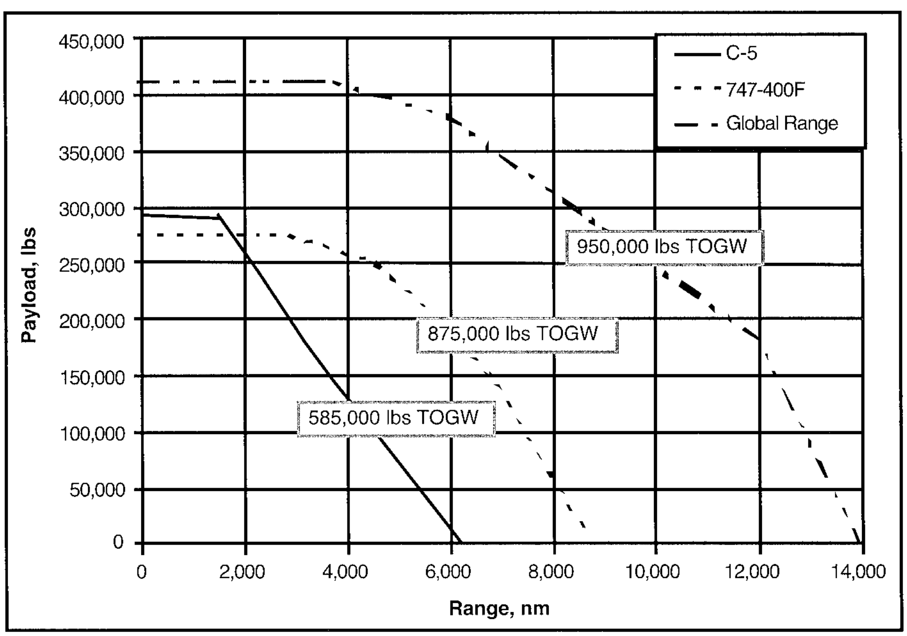

Figure 6.2-5, Payload - Range

Figures 6.2-6 and 6.2-7 illustrate two different versions of such an airplane. Specific configuration development might well yield different vehicles - these are included for illustration only.

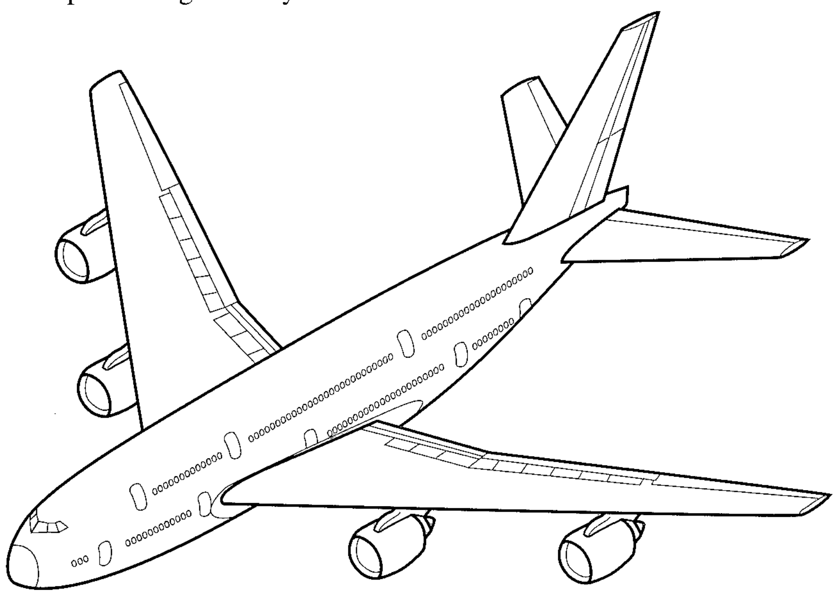

Figure 6.2-6 Global Range Transport Version 1

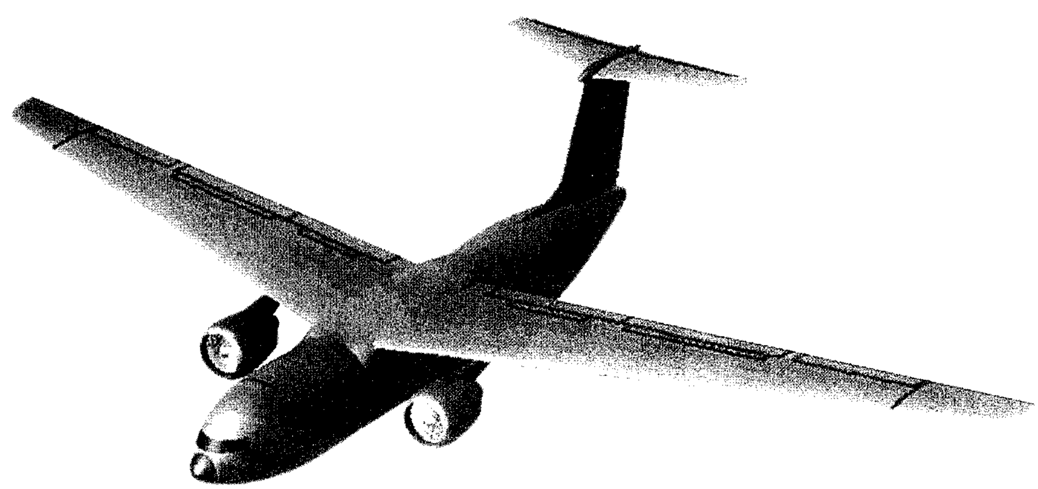

Figure 6.2-7 Global Range Transport Version 2

Benefits

A global range transport, such as described above, will provide AMC the ability to provide rapid response and delivery - of both personnel and equipment - *anywhere in the globe* - to conventional airbases or airports, without the requirement for in-flight refueling. Elimination of the need for refueling these global transports, frees the tanker assets for refueling other inventory transports, and the combat aircraft.

In addition, the global range capability provides greater flexibility in mission planning than would otherwise be available, and will contribute directly to increased AMC mission effectiveness.

Airplane Availability

The availability of C-141 airplanes during Desert Storm ranged from an initial 87% to a final 78%. The comparable C-5 values were 79% and 67%, with a low of 50%. More recently, the C-5A calendar year 1994 average availability was 56%, and the C-5B was 70%. The C-5 goal is 75% availability. KC-10 experience - *with contractor logistics support (CLS)* - for calendar 1994 was 84%. This is dramatically improved over the C-5 experience, and is most likely due to both the newer airplane and systems, and the use of CLS.

The development of a new global range transport that takes advantage of the latest commercial practice in design and manufacturing, in combination with the logistics support concept in use on the KC-10, has the potential of raising the airplane availability rates for AMC to levels comparable to commercial experience, typically 90% or better.

Affordability

Commercial airplane development and production has demonstrated the ability to produce lift capability at significantly less cost than comparably sized transports developed specifically for military use. Some of the cost difference might be due to unique capabilities included in the military transports - but a large part of it is due to the small number of airplanes purchased and the relatively large number of years over which the development and production costs must be spread. There is a lot to be learned from commercial experience.

One objective should be to combine military transport airplane buys with commercial production lines - to take advantage of the larger combined production run, with its associated opportunities for reduced unit cost.

However, an airlifter configured to meet Air Force mission needs may not be 100% compatible with a design that meets the needs of commercial airlines. Research on breakthrough production technologies for military aircraft may offer an affordable alternative. For instance, the Joint Advanced Strike Technology (JAST) program is exploring modular aircraft design and flexible manufacturing systems (FMS) that enable a single production facility to provide substantially different versions to meet the needs of multiple customer and mission requirements. Previously separate production or modification programs for cargo, passenger, aeromedical, platform, or refueling aircraft may provide a means of increasing production runs while avoiding the start-up costs of multiple acquisitions. Over time, the FMS-based production concept may incorporate preprogrammed modernization, service life extension and industrial depot activities to sustain production rate economies.

Commercial Development Potential

An opportunity exists to reduce the cost of acquiring much of the lift capability that AMC needs, by leveraging off of commercial production processes and actual production lines. This opportunity stems from two traditional situations in the military airplane procurement, and an emerging situation in the commercial arena. AMC is effectively one of the world's largest

airlines. Therefore, another objective should be to acquire transport airplanes, and operate them, in a manner comparable to a "world class commercial airline" - for those elements of the AMC mission that do not require unique military characteristics. The operation of the resulting airplane, its maintenance, etc., should also be patterned after commercial practice to the maximum degree possible to achieve the improved availability and reduced operating costs experienced by commercial airlines.

Typically, military production runs are numerically smaller than commercial production runs. Consequently, the development cost of a military transport is spread over fewer units. Additionally, military production is often spread over a relatively long period, with the associated very low production rate (possibly as low as 2 airplanes per month). The low production rate also adversely impacts the "learning curve" of the assembly mechanics (since a relatively long time elapses between repeated tasks), and the quality of the airplane can be adversely affected. Both of these situations increase the unit cost of the resulting airplanes. In contrast commercial production runs are often a thousand airplanes or more, with production rates of 6 to 8 airplanes per month.

Commercial transport airplane design/build processes have recently undergone a transformation that has yielded up to 25% reduction in the cost of production. This rethought design and manufacture technology and organization offers the potential for dramatic cost reduction of military transport airplanes. The digitally based design process, with design build teams involving the builders from the outset, also should provide an opportunity to efficiently develop modest military derivatives from such commercial airplane designs to take advantage of the commercial efficiencies - both design/build and the reduced cost of production. Drastic reductions in manufacturing time spans have been a big contributor to these savings. Further reductions should be expected in the future.

In addition, the military airplanes would benefit from commercial acquisition practice of continual production upgrades. Both commercial and modular production techniques take advantage of continuous production and technology upgrades. This will enable the faster capture of commercial and military technology advancements. As configuration management and maintenance tracking systems become increasingly able to anticipate service requirements of individual aircraft, the cost of maintaining technological currency through more frequent upgrades will become more practical and more affordable.

Technology Requirements

The global range transport needs improvements in three key technology areas. Two of these areas are associated with ongoing development in the field of Engineered Materials. The three areas are:

Increased Propulsive Efficiency

The Integrated High Performance Turbine Engine Technology (IHPTET) initiative projects range increases of 16% to 27% for military transports - depending on size. As noted above, to accomplish the global range capability with an airplane of takeoff gross weight equal to or less than 1,000,000 lbs, significant improvements in the propulsive efficiency will be required. The IHPTET initiative, or similar engine initiative, should be pursued to bring this capability to the design of the global range transport.

Increased Structural Efficiency

A powerful means of achieving desired range is to include an improved structural efficiency in the design. Light-weight, low-cost composites may be one of the elements of achieving this improvement. Work that eliminates the need for tape or ply lay-up during the manufacturing process would appear to hold promise in reducing the cost of such structure. Injection molded thermoplastics will help to drastically reduce part count and help reduce cost.

Increased Aerodynamic/Configuration Efficiency

Finally such a transport development effort should take advantage of opportunities to further improve the aerodynamic efficiency - while not retreating on any of the operating realism required for these airplanes. Improved manufacturing technologies can result in smoother airplane surfaces, with the associated reduction in skin friction drag, and composite primary structure would permit increased lifting surface aspect ratios, with the associated reduction in lift induced drag.

6.3 Precision Airdrop

Since World War II, airdrop of equipment and personnel has been crucial for many forced entry options. Today, airdrop is an operational task of AMC's airlift mission area, applicable to the force enhancement role projecting power by transporting people and material to potential airdrop locations throughout the world. Yet, enhancements to airdrop technology and techniques are essentially unchanged from those of 40 years ago, despite dramatic advances in sensors, computing technology, and guidance, navigation, and control (GN&C). The delivery accuracy of precision guided munitions (PGM) permits us to drop a bomb down an airshaft to destroy an underground bunker, yet it remains difficult to airdrop cargo repeatably within 1,000 feet.

Since precision airdrop was identified as a key technology opportunity in the SAB Global Reach Global Power report in 1992, a better picture of the application of technology to enhance airdrop operations has emerged. This research highlights the importance of airdrop as an integral and important airlift capability.

One principal mission of airlift aircraft is to deploy, resupply, and redeploy combat forces and material during wartime and contingencies. In addition, airlift aircraft are called upon to support humanitarian efforts during emergency situations. Based on the threat, available airfields, and delivery area/target requirements, airdrop (from any altitude) may be the only delivery means available. These missions must be conducted in weather ranging from day visual flight to night weather conditions. As a supporting force under many operations plans, transport aircraft commanders must be capable of quickly deploying and conducting airlift and airdrop operations anywhere in the world. Current and future airlift aircraft will play an ever-increasing role across the spectrum of conflict.

Airlift aircraft are constrained in the airdrop process by the demands of reasonably accurate positioning relative to the drop zone. Once the parachute is deployed, the person or cargo is subjected to deviation from the target by several factors which add up to an "error budget." Eight sequential components of an airdrop error budget include:

- Targeting - Acquire drop zone, determine intended impact point location

- Navigation - Determine and update the aircraft location
- Winds - Measure or estimate winds speed between aircraft and ground
- Performance - Predict the flight trajectory of aerial delivery system (ADS)
- CARP - Calculate the optimum air release point
- Flight Control - Fly the aircraft to the computed release point
- Deployment - Release load and deploy the recovery system
- Trajectory - Descend to the impact point

Description (Details of item, data, sketch, technology enablers)

The application of precision airdrop technology means much more than devising one or two new devices. The most effective airdrop system will include a family of delivery solutions, all integrated with a core support system on board the aircraft. Broadly, the precision airdrop system can be divided into two components: aircraft equipment and the aerial delivery system (ADS). Examples of aircraft equipment include navigation and targeting systems, sensors, computers, and cargo compartment mechanisms. The ADS is that part of the precision airdrop system that comprises the payload , the extraction system, and the recovery system that safely carries the payload to the ground impact point. The ADS may be guided or unguided.

Figure 6.3-1 compares present-day and future goal precision airdrop error. Precision will be improved by applying specific technologies to reduce the relative impact of major error contributors.

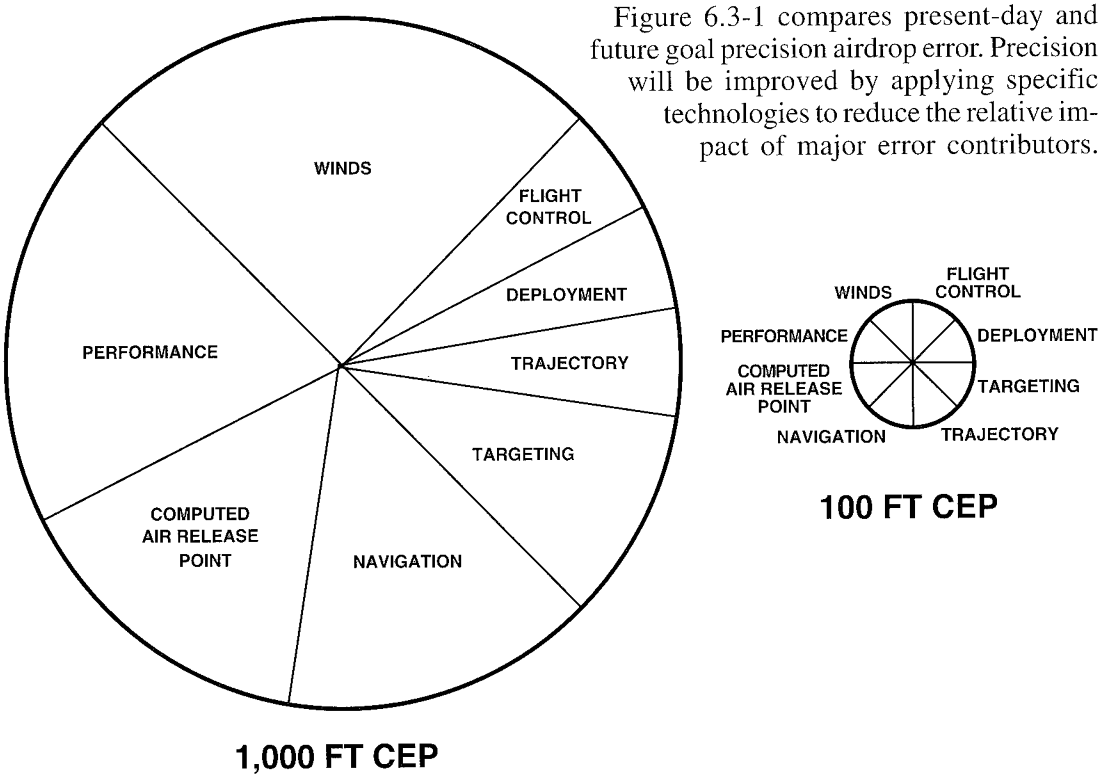

Figure 6.3-1: Precision Airdrop Technology Balances Component Errors (Estimate vs Goal)

The 1992 SAB study set the goal of achieving today's precision from much higher release altitudes.

That is, precision airdrop from 25,000 to 40,000 feet will be as accurate as current airdrop from 300 to 1,200 feet. If this goal is maintained, accuracy at any given altitude will need to be improved by as much as an order of magnitude.

Aircraft Equipment

Airdrop enhancement relies on comprehensive, integrated improvement of aircraft equipment.

- Multiple alternatives provide accurate geographic location of the intended impact point. The complete system incorporates several of these in order to operate in a full range of mission environments.
- Improved navigation systems, including GPS and improved INS, combine ground mapping radar, moving map display, mission flight planning systems, and data fusion from multiple offboard sources.
- Lidar and meteorological dropsondes measure wind profiles and other atmospheric data over the entire trajectory from aircraft to ground. Combined, they provide all weather wind and atmospheric measurement capability.
- Improved aircraft instrumentation provides more precise definition of flight conditions, including altitude, airspeed, ground speed, and direction.
- Continuously computed release point relies on real-time simulation of the ADS trajectory under the measured environmental conditions.
- Control of flight to the release point and release of the ADS is automatically controlled by the autopilot or flight director.

Aerial Delivery Systems

Both existing recovery systems and gliding recovery systems are supported. Figure 6.3-2 shows the range of delivery capability available from a range of ADS types.

- Parachute performance is more predictable based on reduced variability in their design, fabrication, rigging, and packing.
- Guided parafoil systems enable accurate standoff delivery of both light and heavy payloads.
- Deployable wing systems provide accurate delivery from longer standoff ranges for smaller, high value payloads.
- Heavy drop systems place vehicles and other large payloads in close proximity, reducing assembly time. New systems, such as C-5 double-wide platform drop, dramatically increase single drop load weight.

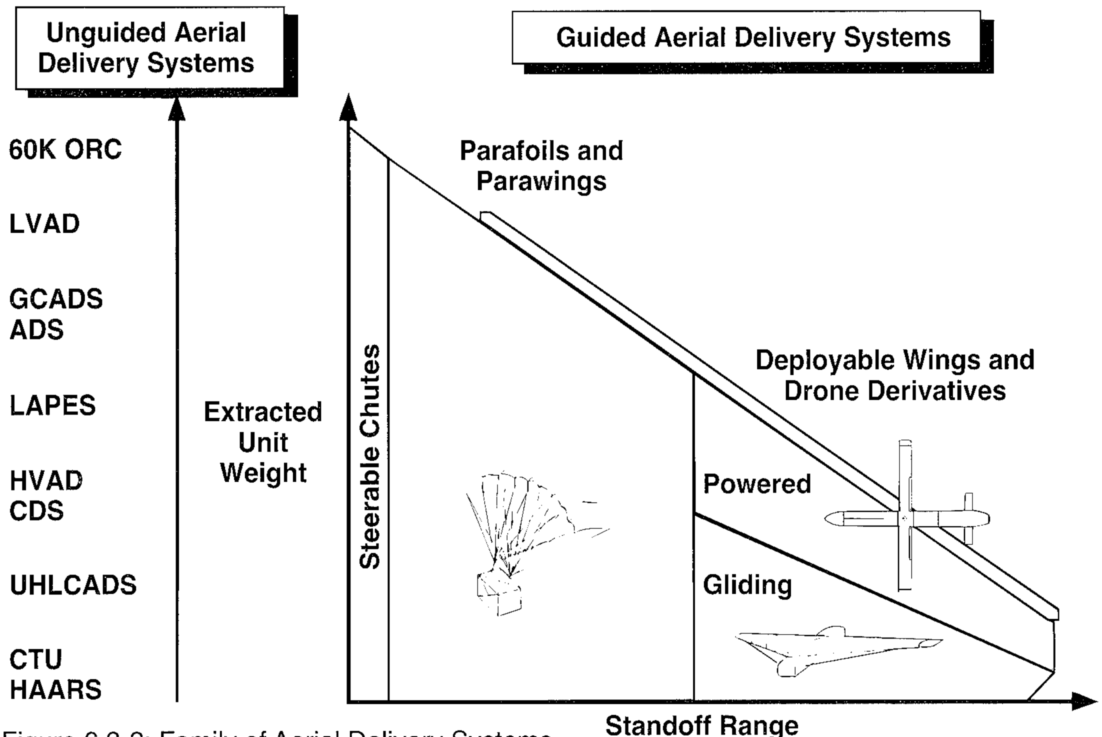

Figure 6.3-2: Family of Aerial Delivery Systems

Benefits

Improved airdrop capabilities, for all altitudes, in all weather, will provide aerial delivery alternatives that enhance mission flexibility, increase safe areas of operation, and complement the rapid forced entry tactics required to counter anticipated threat environments. Precision delivery will reduce drop zone size requirements and assembly times, thereby decreasing ground forces' exposure time to hostile fire and detection. Individual units, and the supplies and specific items of equipment associated with them, can be delivered to preplanned locations within the drop zone, effectively multiplying the number of drop zones available.

Precision airdrop technology can be adapted to support paratroop drops. Paratroopers equipped with steerable parafoils can be guided to their planned unit landing and assembly zones. Figure 6.3-3 shows the concept of a paratrooper guidance system that dramatically reduces the limitations imposed on airborne operations by the length of the drop zone required to get paratroops on the ground. This guidance system can be chest mounted or integrated into a helmet display.

The USAF expects to decrease the size of flight crews and maintenance personnel. Therefore, airdrop enhancement will consider flight deck and maintenance personnel workload and allow a reduction in manpower. Improved systems should be fully integrated with current systems available on today's aircraft. Little additional manpower should be required to either load, maintain, support, or execute the system. The system should be capable of dropping cargo accurately in adverse weather from any altitude.

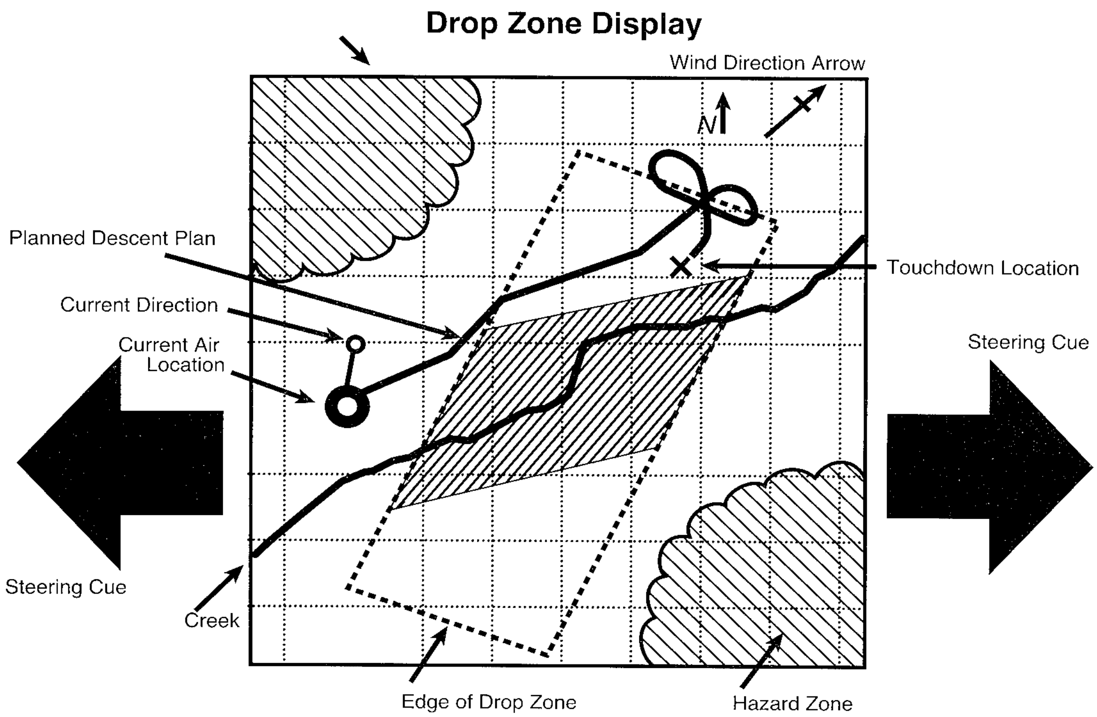

Figure 6.3-3: Paratrooper Guidance System Display

Wind sensing capability, integrated into aircraft flight management systems, can be applied to enhance a broad range of aircraft flight conditions. Lidar can be used to monitor continuously the atmospheric conditions ahead of the aircraft, providing precise range and strength measurements of wind shear conditions and clear air turbulence. Knowledge of both the entry, exit and intermediate velocities can be used to preplan aircraft control responses, thereby minimizing ride roughness and precluding potentially hazardous extreme control excursions. This capability will be especially important during approach and landing in conventional airland operation, and during low-level flight in assault airdrop and terrain-following special operations missions.

Affordability

Precision airdrop enhancement poses little cost risk to future transport aircraft. No major changes are needed to the structure or configuration of the aircraft. Largely, process improvements can be incorporated in aircraft upgrades, including avionics and navigation equipment. Only wind measurement systems are specifically added to the aircraft to support airdrop. Meteorological dropsondes and their dispensers differ little from similar devices in use today. Parallel development of commercial lidar-based turbulence detection systems will minimize cost of production units.

Commercial Uses of Precision Delivery Technology

The significant dual-use airdrop technologies are wind sensing and LIDAR. LIDAR research led to systems that were strong competitors for airport wind shear detection systems.

LIDAR wind sensors on commercial airliners offer dramatic safety improvements. Fuel savings can be realized by using the lidar to look above and below the flight path ahead of the aircraft to determine the flight altitude with the most favorable winds. Continuous clear air turbulence and warning capability permits preplanned reactive maneuvers. Low altitude wind shear detection adds assurance during landing approach and takeoff.

Over the next 10 years, the commercial and military market for airborne LIDAR systems may reach $400 Million.

Civilian and Commercial Uses of Aerial Delivery Systems

Sport parachuting (skydiving) parallels military personnel drops. In fact, many of the innovations in parachuting have been driven by innovation within the sport jumping community. Improved heavy drop capability may provide increased capability to field and supply teams of people performing research or exploration in remote areas, such as petroleum and mineralogical surveys. Thus, companies that own the assets to perform and support remote expeditions constitute a commercial sector to augment demand for advanced aerial delivery systems.

The largest potential civilian application lies in the areas of search and rescue (SAR) and humanitarian relief. SAR is an inherent military mission and the civilian conduct of SAR often is assisted by military organizations. Large-scale humanitarian relief also relies heavily on the rapid provision and use of military assets.

Space programs also constitute a large potential market, especially with the growth of commercial and international launch activity. Research of precision guided parafoil technology of heavy payloads originated as a NASA initiative to find alternatives to parachutes for the safe, reliable and convenient recovery of manned and unmanned space vehicles and components of launch vehicles. The heavy GPADS demonstration has reawakened NASA interest and attracted the attention of the European Space Agency (ESA). Many governments need guided recovery because of their limited access to large, open recovery areas.

Commercial uses will include detectors for clear air turbulence, aircraft wakes, and most favorable altitude winds. Corollary military uses will help reduce costs, including gunship, airdrop, carrier landing, and precision munitions applications.

Near term, precision airdrop will be almost entirely a military application, with increasing civilian and space shares as the technology and support infrastructure matures. Significant export potential will emerge as the international space market grows and as coalition forces increasingly adopt common systems. Over the next 10 years, the emergent market for guided parafoils may exceed $235 million, of which $57 million is due to the space sector.

Technology Needs

A complete precision airdrop system capability requires coordinated development of the following technologies:

- Wind sensing systems, including lidar and dropsondes
- Automatic, continuously computed release point
- Avionics integration of improved airdrop procedures and control
- Advanced cargo compartment, including electric locks, towplate, and parachute initiation
- Guided, gliding standoff aerial delivery systems
- Precision parachute design, fabrication, rig, & pack (innovative redesign)
- Heavy payload precision drop system (double-wide, improved LAPES)

Preplanned improvement relies on coordination with other technology developments, such as:

- Multi-sensor fusion for targeting
- Multi-sensor overlay for real-time flight path planning and optimization
- Use of offboard assets, including satellites, aircraft, and UAVs
- Mission Pre-planning
- Paratrooper guidance system

In the near future, a joint Advanced Technology Demonstration (ATD) of precision airdrop capability should be conducted. USAF should emphasize improvements to the aircraft that support all aerial delivery systems. Primary sponsors should be the Air Force and Army, but other potential users should be involved, including Special Operations, Marine Corps, and Search and Rescue.

6.4 Directed Energy Defensive System

Background

Air mobility forces are required to operate during worldwide employment, deployment, resupply, and retrograde operations at all levels of conflict. Active duty and Air Reserve component airland and airdrop wartime missions require operations within and around hostile air defense systems. During peacetime, mobility aircraft routinely operate in areas of civil unrest, insurgency, and in the presence of terrorists and counternarcotics activities.

The most significant current threat to air mobility aircraft is the worldwide proliferation of IR-guided, surface-to-air missiles (SAMs) during low altitude operations, particularly during takeoff/initial climb and approach/landing. Equally disturbing are the hostile aircraft launched IR missiles for which slow moving large aircraft are especially vulnerable. Today air mobility assets are not equipped to counter this threat, and even low attrition rates from hostile air defenses and terrorists can have adverse effects on mission accomplishment. Loss of even one high priority mobility aircraft could equate to other unsuccessful missions in a critical environment.

The most pressing threat remains the shoulder-launched IR-guided missile and they appear to be more widely available than ever before. The guidance technology embodied in these missiles varies greatly from the current Quad cell to reticle-scan to more advanced forms, but all can be lethal to large air mobility-sized aircraft. These aircraft present a large IR signature and are particularly vulnerable during slow low-altitude approach and landing as well as take-off phases of operations. The task of defending against this threat is very real and must be solved soonest.

The SAB in the 1990 and 1992 Summer Studies concluded that the problem of air mobility aircraft self-protection against missile threats was significant and that a concept for killing threat missiles or disabling their guidance systems was needed.

Air Mobility Command is well aware of the importance of this threat and has formally issued a statement of need (SON), mission need statement (MNS) and an operational requirements document (ORD; 1 July 1994).

Description

What is needed is a countermeasure support system that, because of the aircraft's large size, functions autonomously using a missile approach warning system and sophisticated computer that triggers flares or decoys and/or some form of missile killing or guidance disablement system.

The first requirement is to provide air mobility aircraft with missile warning systems. The aircraft cannot be defended if an approaching threat missile cannot be located. Missile warning systems have been developed that provide relatively good azimuth, elevation and range information for RF acquisition and tracking systems. However, missile warning systems for IR-guided, ground and air-launched missiles, is sorely lacking. Two recent USAF/Navy programs attempted to address this shortfall. The Missile Attack Warning System (MAWS) and Silent Attack Warning (SAW) systems both focused on the IR missile threat, but have had problems due to insufficient funding. The Advanced Threat IR Counter Measure (ATIRCM) program is the latest joint initiative to solve the IR missile warning problem. This Army-led program inherited the MAWS program and schedule. The program was renamed the Common Missile Warning System (CMWS). The contractors bidding for the ATIRCM/CMWS contract may propose full coverage IR search and track (IRST) sensor systems, single or array detector systems, UV, MMW and other sensor ideas that will acquire and track incoming IR (or other passive seeker) missiles.

Second, there needs to be a dedicated high-performance computer to provide the high-speed calculations necessary to predict an oncoming missile's flight trajectory and impact points. Small massively parallel computing processing begins to offer the capability needed to autonomously control a missile-defeat or guidance-disabling or killing system.

Third, there is a need for automatically activated countermeasures against approaching missiles. Decoy or spoofing is an attractive solution for the 1970-1990 developed IR missiles. Reticle-scan arrays may be pulled off a target aircraft by the newer flares or some decoys if appropriately used. These devices frustrate the missile's attack during its homing phase. The timing of the employment of flares and decoys is critical for large, slower-speed aircraft. Autonomous dispensing of flares and other decoys must be coordinated and controlled by the missile

approach warning system and its high performance signal data processing system. The aircrew must be aware of the "system" activity so that intervention and flare rejection is possible in certain operational situations.

A more difficult problem is presented with the employment of more advanced IR missile seekers. The focal plane array detectors are not routinely deceived by flare or decoy systems. Therefore, missile destruction or seeker confusion is an attractive solution for large aircraft capable of carrying such a system.

The use of directed energy weapons, either laser or high-power microwave energy, appears to be a relatively near-term possibility. This provides the targeted aircraft an opportunity to "shoot back" at the approaching missile. Although these missiles are small targets, very fast and highly maneuverable, there is a developing laser technology that, within a twenty-year time frame, offers the potential solution.

In the past, lasers with sufficient power to be lethal against approaching SAMs and other missiles have been too heavy and bulky to be practically employed. However, there has been considerable work that will lead to a smaller, lighter weight laser system that is both adequately lethal and sufficiently compact to be practical as an adjunct self-defensive weapon. This means attacking the target missile with a small diameter but high irradiance (Watts/cm^2) laser beam and penetrating rapidly and deeply into the guidance sensor or the controls subsystem. Such a small energy-frugal system is estimated to take 5 to 10 years of development time at a cost of under $250 million. It is estimated to weigh less than 500 pounds, be packaged in a 3'x2'x2' space, deployable internally or in a pod. Prime power requirements for the very short-duration of laser firing should be less than 150kW. For more information about this 1.06 micron system refer to the Directed Energy section of the 1995 SAB report.

An alternative directed energy solution to missile interdiction is the use of High-Power Microwave (HPM) energy. Advantages to HPM in aircraft defense are that it is effective in all weather operations, and it puts much less strain on pointing and tracking requirements. HPM weapons will probably progress from (1) electronic interrupt precluding missile closure, (2) electronic component burnout causing permanent damage, to (3) potentially catastrophic kills involving warhead detonation out of harm's way. Studies are under way involving engineering solutions to the affects of HPM on the host aircraft's electronic components and subsystems (fratricide). Recent experiments suggest that survival of one's own assets is possible. Transitioning this technology into robust application is very possible within the next 10 years for mobility aircraft (20 years for fighters). For more details see the Directed Energy Section in the 1995 SAB report.

Another interesting countermeasure concept involves the use of a self-protection missile (SPM) launched from an air mobility aircraft. These SPMs would be triggered by the missile warning system and launched by computer-driven instructions.

The SPM is based on a design being developed by the Ballistic Missile Defense Office (BMDO). These vehicles employ reaction thrusters to suspend, stabilize, and maneuver. Since they can operate at low or zero velocity, they can separate from the launch aircraft from any direction, making 360 degree defense feasible. Interestingly, several SPM type vehicles have been hover-tested at Edwards AFB. Several have been launched at White Sands Missile Range with partial success.

The proposed SPM guidance could be millimeter wave radar, or IR imaging, or inertial if warhead breakthroughs occur. Note that guidance and control of the SPM is simplified by the nature of the encounter with the attacking missile. The missile seeker is locked onto the target aircraft, so in the initial stages its radar cross section is very large. Furthermore, the attacking missile attempts to fly a collision course with the target aircraft. That zero line-of-sight trajectory simplifies the flight path of the SPM. Killing and disabling mechanisms include first allowing the on-coming missile to run into the SPM (kinetic kill), providing a very small warhead, or by using a miniature High Power Microwave warhead. Each SPM should weigh between 100 and 200 pounds.

Benefits

The preferred solution of a directed energy defensive system is essential to continued air mobility operations in the 21st century. The problem of IR (UV or MMW) launched missiles is proliferating to the point where C-5s, C-17s or other air mobility assets are extremely vulnerable in any unfriendly environment. The benefit for AMC is protection of these high-value assets and continuation of the air mobility mission. AMC should engage the scientific, technical and development communities now to get the directed energy system in the acquisition cycle. The SAB mobility panel believes the small laser offers the most immediate solution.

Affordability

The directed energy "offensive" systems have some generic technology development money but no advanced development program or demonstration dedicated to the lethal self-defense of large aircraft. The Navy has expressed interest in collaborative efforts using the assets which are in place now on a Navy P-3, i.e. a prototype MAWS threat warning device and an ATIRCM Tracker . Handover from the MAWS to the tracker has been demonstrated this year and this equipment will be used together with an open loop jamming laser on a Navy IRCM ATD in the FY96-98 time frame. The Navy activity aspires to transition to a follow on fighter protection system , but the Navy system could provide an early flying test bed for the advanced light weight high precision tracking concepts which are central to energy frugal approaches to both sensor damage in the 2005 time frame and lethal self defense in the following decade.

The laser development activity needed to provide the technical basis for lethal self-defense systems is substantial and essentially unfunded. While industrial/commercial laser activity may provide some collateral support (see below) such activities are unlikely to aim towards the compact, essentially self-contained systems needed. Commercial success may involve similar laser powers but the key ingredients for commercial activity are: (1) low capital cost and (2) low production down time for repairs and maintenance. These typically lead to simple, robust (and heavy) optical trains and a rather open architecture, versus dense packaging, to facilitate maintenance. Raw power is also likely to be more important than high beam quality. There is some degree of Navy interest in examining options other than chemical lasers for Directed Energy Weapons (DEW) against anti-ship missiles as well as some more tenuous indications of Army interest. With some further work to develop point designs, a basis could be found for collaborative work at the 6.2/6.3 level to define and establish key benchmarks for a joint program. This may be more supportable in the present climate than single service initiatives.

Commercial Development Potential

Many of the features of the solid state lasers make them attractive as DEW lasers. Examples are electrical excitation at moderate voltages (approximately 28 to 600volts), non-toxic effluents (essentially warm water) and closed cycle operation with no, or very few, consumables. These features would also recommend these lasers for commercial application. However, the commonality is much more likely to be at the component or subsystem level than at the level of complete devices. However, because commercial laser designs are heavily cost-driven, there is always the possibility that the trade-off will yield cheap, but inefficient components.

In past cases, collateral commercial laser development might help maintain low prices for some components but would not affect the most expensive components. A recent example is the two micron solid state medical lasers. A major commercial market has grown up for 40-50 watt lasers for arthroscopic surgery; this market had its genesis in DoD work to develop two micron diode pumped lasers for IRCM. The commercial presence has been very beneficial in laser crystal development and pricing. For example, per unit volume, the cost of Chromium, Thalium, Holmium, and YAG crystals is essentially the same as Nd:YAG, as is the quality. However, the medical lasers use flashlamp pumping rather than laser diodes for cost reasons, as a result the cost of laser pump diodes has stayed essentially flat over the past four to five years. In discussions with industry, the current cost of pump diodes, \$10-15/peak watt, and \$50-75/average watt, would have to decline by a factor of five for a diode pumped device to be competitive in the marketplace. Similar economics apply to diode pumped Nd:YAG lasers.

Unless some highly attractive volume commercial market opens up where diode pumped lasers are the only solution , there is essentially no commercial force at work to drive down diode costs. There does however seem to be history which argues that if the DoD developed such a low cost production capability, commercial demand for the product would help to sustain the low price with a steady market.

Technology Requirements

The solid state DEW device would require the development of:

- Suitable laser host-dopant combinations. Ytterbium in a garnet crystal such as YAG or GSGG would appear a reasonable baseline choice which would offer spectrally broad pump bands (reduces temperature control requirements on the diodes), long upper laser level lifetime (reduces the number of diodes), high heat capacity host (reduces the temperature jump for a given heat input) and high thermal diffusivity and shock resistance (high average power handling capability).
- Cheap and high reliability laser pump diodes at 948 nanometers.
- Laser mode control/phase conjugation concepts and components.
- Uncooled low loss optics at 1.0-1.05 microns.
- Light weight pointer/trackers with active beam correction
- Complete system point designs are needed to highlight thermal and electrical control requirements.

6.5 Virtual Reality Applications

Background / Introduction

The virtual training environment of the future will link real and simulated assets around the world, representing air, sea, land and space systems, advanced or fictitious threat systems and virtual and real participants immersed in synthetic environments It will provide almost limitless potential to develop and assess scenarios and tactics, and allow for initial and proficiency training at low costs in safe environments. Realistic sensory immersion will greatly enhance human task efficiency, improving the effectiveness of operational employment and training. Virtual reality training promises to complement actual in-flight training and dramatically increase the readiness and overall effectiveness of Air Mobility Command forces.

System Description

The Air Mobility Command Virtual Reality Training System (VRTS) will be a modular, mobile, high fidelity, globally distributed training and evaluation system that combines real world and synthetic assets and environments to provide a virtual training scenario indistinguishable from reality.

The AMC VRTS will be a distributed set of systems that can be integrated, configured and reconfigured rapidly and easily, thereby maximizing flexibility and affordability. This single "system of systems" will be employed for multiple types of simulation and training for all mission areas and supporting tasks for AMC. It will consist of networks of computational and physical / sensory systems as configured in Figure 6.5-1:

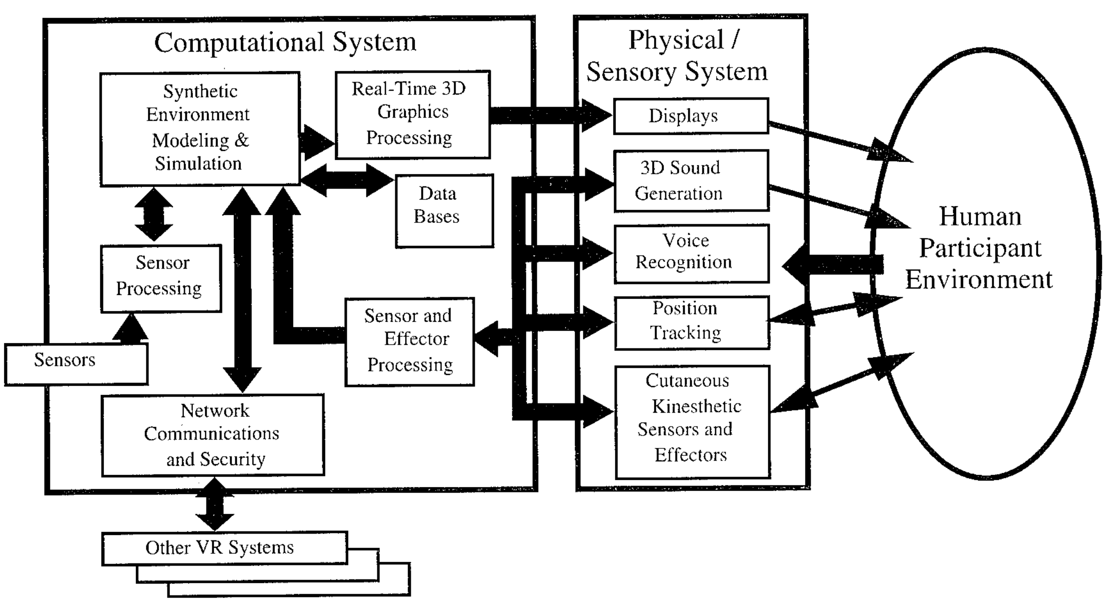

Figure 6.5-1: Architecture of Synthetic Summary Environment

The computational system that generates the immersive environment itself is made up of the following advanced technology systems:

- Advanced computer systems will provide the enormous data/information and sensor processing required to create the synthetic environments, network with the other real and virtual assets in the environment, and run the simulation software. Advanced simulation techniques (software/ hardware) are required to create and integrate the disparate elements of the virtual world into a synthetic environment that is simultaneously all-encompassing yet individually commanded/controlled.

- Real time, high speed, high bandwidth datalinks, data compression techniques and Time Division Multiplex Addressing techniques (or future technologies) enable the transmission of large amounts of data to multiple participants simultaneously. Satellite links provide over-the-horizon and even global communcation and participation.

- Integrated differential GPS provides accurate Time Space Position Indication of real, globally employed assets such as aircraft, ships, tanks, airfields and soldiers, as well as sub-elements of assets such as tank turrets or precision guided weapons.

- Multi-level security systems must be included to ensure no participants, data or other elements of the system are compromised. The ability to provide a secure environment while running with other unclassified or commercial systems in a realtime, globally distributed, interactive exercise is the goal. Virtual simulation, coordinated with ongoing field operations will be an evolving acqusition challenge.

The physical/sensory system provides the man-environment interfaces, and represents the most stressing technology challenges as follows:

- Efficent interactive visualization tools and environments are employed to create a virtual physical environment in which the participants interact and work. While displays are currently used to provide the imagery and human interface, displays will eventually be replaced by systems that allow seamless overlays of synthetic environments by projection, holographic or other mechanisms such that the participants perceive themselves to be immersed in the environment instead of observing it.

- Hardware and software are employed to provide sound sources as well as to implement voice recognition processing. Magnetic, acoustical and optical sensors will be employed to ascertain and track the participants in the environmental simulation. The sensation of touch, sense of resistance and motion will be generated through software and appropriate hardware devices.

The human participant environment consists of:

- The individuals and the crews of exercising units participating in a virtual reality training scenario.

Benefits to Air Mobility Command

AMC mission effectiveness and readiness will be enhanced through the comprehensive employment of VRTS across AMC missions and tasks. VRTS will enable actual in-flight and simulated AMC assets to participate directly in air mobility mission operational exercises for readiness and joint service interoperability training. It will enable AMC to conduct multilateral system and maintenance initial and proficiency training at multiple sites. It will be possible to enter a virtual environment and develop and verify critical airlift concepts or maintenance tasks on emerging weapons systems and to evaluate new concepts for ground handling equipment. In addition, it will be possible to conduct mission rehearsal scenarios involving the movement of troops or cargo through an intermodal system to assess routing effectiveness and conduct sensitivity analyses.

In addition to generating realistic environments for initial and proficiency training, VRTS can be employed to create special purpose tailored environments to provide an unprecedented level of command, control and communications of widely distributed air mobility assets. This virtual C^4I environment allows for direct human contact of all critical individuals involved in globally dispersed events as if they were co-located in the same room. All elements critical to mission success can be displayed and analyzed in real time in one virtual room by globally distributed personnel. Experience from Desert Storm has shown that person-to-person contact is a significant contributor to force effectiveness, especially in highly dynamic situations.

Affordability

While establishing advanced virtual reality capabilities will probably be pursued commercially, the development of secure systems may be expensive. However, the ability to participate in exercises with other services and to conduct large-scale operational training will be highly cost-effective. Heavy reliance on commercial computer, image generator and projection developments will help keep this affordable.

Commercial Development Potential

First generation limited virtual reality simulators exist today. Improving and extending these to include military unique requirements (i.e. secure, wideband data links) will be beyond the commercial realm. However, the Air Force will still be able to take advantage of basic commercial development to provide the foundation for virtual reality systems.

Technology Requirements

Virtual Reality systems holds great promise for quantum improvements in air mobility training, but the technology challenges are large. Some individual technologies are realatively mature, while others are less mature, even embryonic. The DoD, commercial industry and government, need to coordinate requirements and research and technology development efforts across critical technology areas. Near term efforts on the Joint Combat Training System and the development of Virtual Strike Warfare Environment for the Joint Advanced Strike Technology program are opportunities to demonstrate the initial milestones of distributed virtual simulation and represent initial steps down the path toward the Virtual Reality vision.

Key technologies and their levels of risk along with the required investment to reduce risk are shown in Figure 6.5-2: Relative Investment Risk of Visual Reality Technology.

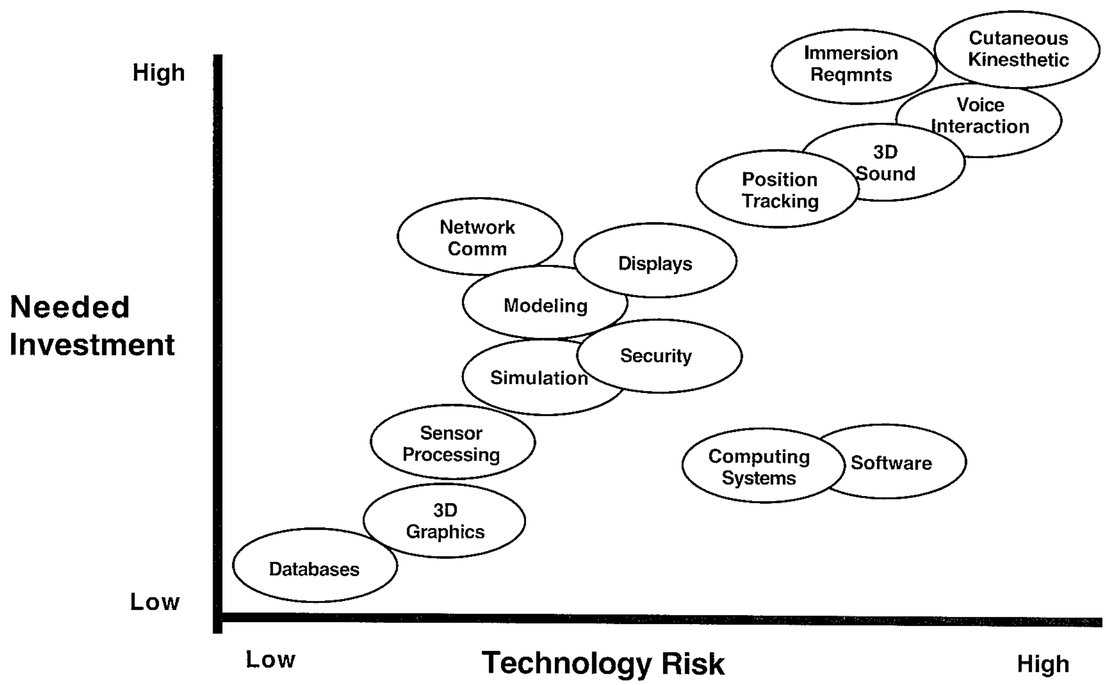

Figure 6.5-2: Relative Investment Risk of Visual Reality Technology

7.0 Summary and Conclusions

The Air Mobility Command must have the capability to support operations anywhere in the world from the continental US. To do this they need secure, dependable, worldwide information/communications and global range transports. Advanced technology offers the opportunity to satisfy these needs at reasonable cost. Commercial developments of satellite and fiber optic communication systems will provide global, wide bandwidth data capability. These systems should be the bases for the necessary communications for global reach mobility.

Continued development of advanced materials should support two elements critical to global range. Advanced high temperature materials will be the key to major improvements in engine performance. The second will be the development of low cost composites. Developments on the F-22 with injection molded thermoplastics point the way to low cost major structural components with very few parts. Continued emphasis on low-cost manufacturing of advanced materials should make it possible to have lower weight (longer range) transports in the future. Another benefit of the low-cost manufacturing (and reduced part count) is improved smoothness and aerodynamic efficiency. These will all contribute to a new transport weighing under a million pounds and capable of carrying 150,000 pounds of payload for 12,000 nautical miles.

The requirements to support operations in remote areas will place a premium on improved airdrop capability. Most of the elements exist today to do large-scale (60,000-75,000 pound) precision airdrop. However, a more accurate GPS navigation system, wind profile measurement, and improved delivery systems must be integrated to effect this capability. A big challenge is to invent a low-cost delivery system to replace the parasail.

An advanced technology which can really help mobility aircraft is directed energy used as a defensive system. Mobility aircraft do not have the agility to evade missiles, but can provide the space and power needed to utilize the logical applications of this technology. It will provide a much needed survivability enhancement.

The advanced technology of virtual reality can enhance mobility training. The use of computer-generated imagery and advanced three-dimensional holographic displays can improve training, operational planning and rehearsal training. These will be possible by combining simulators and real equipment at distant locations *via* wide bandwidth data links. There will be commercial developments of virtual reality which will make it easy for the Air Force to adapt. The mobility command will benefit from the improved level of reality and it will aid them in also adapting to worldwide communication developments.

The key elements of the recommended advanced systems are summarized in the table 7.0-1.

Table 7.0-1: Mobility Recommended Systems

	Information Dominance	Global Range Transport	Precision/ Large Scale Airdrop	Directed Energy Self-Defense	Virtual Reality Applications
Importance to Air Force	Vital for C^4I, supports RTIC	Supports all global reach missions	Improves flexibility and survivability	Improves survivability	Joint exercises and training
Effectiveness benefit	Improves C^2 and survivability	Improves reaction time and reliability	Reduces forward infrastructure	Increases probability of mission success	Improves mission effectiveness
Affordability	Moderate	Good	Moderate	Moderate	No impact
Key Technical Issues	Wide-band global C^4 and Nav nets	Low-cost composites, very high performance engines	Wind Measurement	Low power laser and system integration	Synthetic environment generation, physical sensory systems
Commercial Development	Yes, but needs tailoring	Probably	Limited	No	Yes, but needs tailoring

Appendix A

Panel Charter

- Select areas of rapidly changing technology applicable to Mobility Mission
- Identify most revolutionary technologies
- Predict impact on affordability of Mobility Mission
- Identify which technologies can be obtained by capitalizing on commercial development
- Identify solely military technologies

Appendix B

Panel Members and Affiliations

SAB Members

Mr. Robert Patton, Chairman
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Appendix C

Panel Meeting Locations and Topics

5-6 April HQ AMC, Scott AFB, IL

An orientation to AMC missions was obtained. Briefings were presented on the Air Mobility Master Plan, TRANSCOM's DTS 2010 reengineering efforts, C-17 and NDAA, MHE, C4, and modernization programs as well as AMC's deficiencies. A tour of the TACC was also provided.

2 May Lockheed-Martin, Atlanta, GA

A review of Lockheed-Martin's mobility research was obtained. Briefings were presented on mobility requirements analysis, advanced mobility concepts, and views on future technological improvements needed. A tour of Lockheed-Martin's production line facilities was also provided.

3-5 May Maxwell AFB, AL

Spring Workshop was attended. Focus of workshop was on science and technology goals for future AF needs. Short panel working meetings were held, and panel members participated in various working groups to explore the capabilities, science and technology, and concepts for the future.

7-8 June Boeing, Seattle, WA

A review of Boeing's mobility research was obtained. Briefings were presented on the 777 program and technical improvements and operational changes which made it successful, the F-22, 747-400 NDAA, 767 tanker, and other potential aircraft programs and on-going design and materials work. A tour of Boeing's production facility was also provided.

14 June TRADOC, Ft Monroe, VA

A review of future Army mobility requirements was obtained. Briefings were presented on TRADOC's strategic plan, Force XXI Operations and Joint Venture, and the Army's Battle Laboratory programs.

Appendix D

List of Acronyms

Acronym	Definition
AE	Aeromedical Evacuation
ADS	Aerial Delivery System
AR	Aspect Ratio
ARTC	Air Refueling Transfer Craft
ATCALS	Air Traffic Control and Landing System
ATD	Advanced Technology Demonstration
ATIRCM	Advanced Threat Infra red Counter Measure
C^2	Command and Control
C^4I	Command, Control, Communication, Computers and Intelligence
CARP	Circular Area of Probability
CMWS	Common Missile Warning System
COTS	Commercial Off-the-Shelf System
CRAF	Civil Reserve Air Fleet
DPG	Defense Planning Guidelines
ESA	European Space Agency
GCCS	Global Command and Control System
GN&C	Guidance, Navigation and Control
GNS	Global Navigation System
GPADS	Guided Precision Airdrop System
GPS	Global Positioning System
HPM	High Power Microwave
IHPTET	Integrated, High-Performance Turbine Engine Technology
INS	Inertial Navigation System
IR	Infra red
IRST	Infra red Search airTrack
ISAM	Intermodal System for Air Mobility

ISO	International Standards Organization
IW	Information Warfare
LAPES	Low Altitude Parachute and Extraction System
L/D	Lift over Drag
LIDAR	LIght Detection and Ranging
MAWS	Missile Attack Warning System
MHE	Materials Handling Equipment
MMW	Millimeter Wave
MOG	Maximum aircraft On the Ground
MRS	Mobility Requirements Study
MRS BURU	Mobility Requirements Study Bottom-Up Review Update
MTM/D	Million Ton Miles per Day
NCA	National Command Authority
NDAA	Non Developmental Airlift Aircraft
NVG	Night Vision Goggles
OPSEC	Operations Security
OSA	Operational Support Airlift
PADS	Precision Airdrop System
PGM	Precision Guided Munitions
R&M	Reliability and Maintainability
RTIC	Real-Time Information in the Cockpit
SA	Situational Awareness
SAM	Special Air Mission
SAM	Surface-to-Air-Missile
SAR	Search and Rescue
SAW	Silent Attack Warning
SIOP	Single Integrated Operational Plan
SOCOM	Special Operations COMmand
SPM	Self-Protection Missile
STOL	Short TakeOff and Landing
TPFDD	Time-Phased Force Deployment Data

UAV	Unmanned Aerial Vehicle
USSTRATCOM	US Strategic Command
UV	Ultra violet
VR	Virtual Reality
VRTS	Virtual Reality Training System
VTOL	Vertical Takeoff and Landing
WBE	Wide Body Equivalents
WIG	Wing in Ground
WWMCCS	Worldwide Military Command and Control System